Bower

SIMPLE EXPERIMENTS

FOR

SCIENCE TEACHING.

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SIMPLE EXPERIMENTS

FOR

SCIENCE TEACHING,

INCLUDING

TWO HUNDRED EXPERIMENTS FULLY ILLUSTRATING THE ELEMENTARY PHYSICS AND CHEMISTRY DIVISION IN THE EVENING SCHOOL CONTINUATION CODE,

BY

JOHN A. BOWER,

AUTHOR OF "HOW TO MAKE COMMON THINGS," ETC.

"Search out the secrets of nature by way of experiment."—PALEY.

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PREFACE.

THIS is essentially a book of experiments. Most of them are very simple, and can easily be performed by those who have never tried an experiment in their lives. No expensive apparatus is employed in this course of experiments. All the contrivances can be made from the homeliest things, such as tumblers, saucers, basins, and pans employed for ordinary household purposes.

We have often heard from teachers that a course of Lessons in Experimental Science would be very acceptable "if the apparatus were not so expensive." This difficulty we hope to have overcome to a great extent—not that we depreciate good apparatus and beautiful contrivances—but we wish to show that a good start can be made without them.

This course is designed for the teacher and the pupil, especially for the teacher who has not been able to have the advantage of a training in "Science Teaching with Experiments." We have given the

most minute directions for the performance of all the experiments, and the experiments should in every case be rehearsed before showing them to a class.

In our country villages, where Technical Classes for Science Teaching would be formed but for the expense of getting a teacher or lecturer experienced in this class of work, we hope these experiments will especially recommend themselves. We would also say to such teachers—"Get a chance as early as possible of attending one of the County Council classes, where Experimental Science is taught specially for the teachers."

To pupils who have no teacher we also hope the book will recommend itself. It opens a way, not only to learn something of science by experiments, but it also gives directions for making simple apparatus for performing the experiments.

Science taught by experiments is the only method by which we really get to know anything about Nature, which is all round and about us. We may learn a glimmering of things by reading about an experiment and performing it in "the abstract"; but when we have actually gone through it, we are not so likely to lose sight of what the experiment was intended to teach, and it will be all the more impressed if we actually put together and arrange the things by which the experiment is performed.

Instead, then, of merely reading, we hope this course of experiments will bring many inquirers,

of Nature into the field, which will open a wider and wider view as they get on.

To the teachers who adopt this course we will say one word more—have only the apparatus before your class that you intend to use, and do not try an experiment unless you have already performed it quietly by yourself. Then by conversation, and questions to the pupils and from the pupils, let the object of each experiment be fully thrashed out, so that every one understands what the experiment was intended to teach. Then let the pupils perform the experiments themselves. It is only by this means it can become real Science.

Each lesson of ten experiments is enough for an hour's work, for it is quality not quantity that makes Science teaching really useful. Science should teach us to observe, think clearly and accurately, and to aim at getting at the truth of everything. By this method of working it will become not only a branch of education but a means to education. All our other work should be better done for having such a training.

The course given in this volume includes the whole of the "Physics and Chemistry" in the first two sections of the Code for Evening Continuation Schools. For these and every other class where Elementary Science is being taken for those who are beginners, we hope this course will be especially fitted. We have not drawn any great

line of distinction between a physical and chemical experiment, it is not necessary; neither have we given any long explanations about the experiments: there are so many excellent books that will do this, and every teacher has his favourite text-book.

JOHN A. BOWER.

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SIMPLE EXPERIMENTS

FOR

SCIENCE TEACHING.

LESSON I.

STANDARDS OF MEASUREMENT.

ALL things about us have size. We get very little information when told that one object is taller or bigger than another. We must know the height or size of the object with which the comparison is made.

That height or size would be our Standard. A standard is something that always remains the same. The simplest standard of measurement is one of length, or measurement in one direction only. The English standard and its divisions are given in your table-books, and read thus—

12 inches make 1 foot.
3 feet „ 1 yard.

The yard is the standard of length.

It is called the "Imperial" standard of length, because it is the standard established by law. The

yard-measures used by drapers and others for measuring off material are as near as can be of the same length as this standard. The standards themselves are kept in places of safety. If you have not seen a standard yard, you may perhaps like to hear something about it. It is a bar of bronze, 38 inches long and 1 inch square. Near the ends on one side you will see two round spots, which are really gold plugs let into the bar; across these you will find sharp lines marked. Between the marks at the opposite ends of the bar is exactly 36 inches, *i. e.* the bar is divided into 3 equal parts, called feet, and each of these into 12 equal parts, called inches. As a bar of metal gets longer in hot weather and shorter in cold weather, it is necessary to fix on a certain temperature when this bar measures exactly 1 yard, that is 62° Fah.

One standard is at the Royal Mint, another in the keeping of the Royal Society, a third at the Royal Observatory, Greenwich, and the fourth at the Houses of Parliament. Outside the Greenwich Observatory, in one of the walls near the clock, two pegs are put in for the general use of those who want to test a yard-measure; the same is done for the foot and inch. The standards themselves are preserved with great care.

For experiments you require a good standard measure. Provide yourself therefore with a steel foot-rule, on which several scales besides the mere English measures and divisions are marked. It will cost you 2*s.* 6*d.*

Experiment 1.—Take a strip of cardboard, 1 inch wide and 1 foot long, cut the ends square with a sharp knife, and keep the edges very even. With

a finely-pointed hard pencil divide it into 12 equal parts; number them from 1 to 12. Draw a line along one edge, at one-eighth of an inch from the edge. Now divide each inch into eighths, marking the half-inch divisions half-an-inch long, the quarter-inch divisions quarter-inch long, the others merely to the mark along the edge. Having done this, draw a similar line along the other edge, and divide each inch into tenths, making the half-inch divisions a quarter-inch long, the others merely to the line. We give in the diagram (Fig. 1) an illustration of this divided foot-measure. Make the divisions very carefully, and you will have a reliable foot-measure. Use it carefully also.

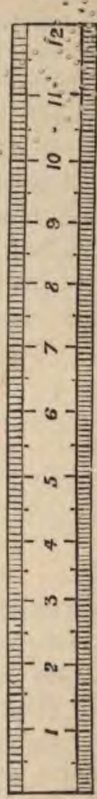

Fig. 1.

Experiment 2.—Cut two similar strips of cardboard, each a foot long; divide them into inches only, but be as careful in your work as in the last. Now put these three foot-measures together, end to end, and test as many reputed yard-measures as you can borrow; see if they agree with your standard measure. If they do not, see how much per yard they differ. Multiply the inaccuracy by 20, 50, 100, 1000, and you will then see how a small inaccuracy in a short length becomes a large one when repeated over a long distance.

When the names yard, foot, and inch were first used, they did not express any exact lengths. The

foot meant roughly the length of a man's foot, the inch the measure across the thumb, the yard the length of a man's arm. Now these are standard lengths, and the rest of the measures in your table-book are either multiples or divisions of the yard. The carpenter generally uses a "two-foot" rule, the surveyor a pair of five-foot rods.

In our science books another standard of measurement is now greatly in use; we must therefore ask you to take pains and make yourself as familiar with that as with the English. It is called the "Metric," because a measure called a "Metre" is used as the standard. It is the French unit of length. We will give you the table of length, then we must ask you to compare the English with the French measure.

The Metric Measure of Length.

10 millimetres (mm.)	=	1 centimetre.
10 centimetres (cm.)	=	1 decimetre.
10 decimetres (dm.)	=	1 metre.

The multiples of the metre are given as follows—

10 metres	=	1 dekametre (Dm.).
10 dekametres	=	1 hectometre (Hm.).
10 hectometres	=	1 kilometre (Km.).

The English yard, as we have said, = 36 inches, and the metre = 39·37043 inches, measured at 0° C.; but 39·382 inches when like the English bar measured at 62° Fah., or the yard is ·9144 of a metre. For ordinary comparison we can use $39\frac{3}{8}$ inches as the length of a metre, and 4 inches as the length of a decimetre. Look at the two, the decimetre and 4-inch measure, in Fig. 2. The standard English metre is a platinum bar, and was made a legal measure in England in 1864. Both the metre and yard are absolute Standards

of length. The ordinary metre measures are made in wood, like our yard-measures.

Note the irregularity of the English divisions, and the regularity of the Metric divisions. The English has 12 inches to the foot and is called the duodecimal system, the Metrical has divisions of 10 and is called the decimal system. The prefixes used in the Metrical system tell at once what part of a metre it is, for milli = thousandth, centi = hundredth, deci = tenth; then again in the multiple measures, deka = ten, hecto = hundred, kilo = thousand.

Reduction of higher to lower divisions, or *vice versâ*, require no multiplication, as we have in the reduction of English measures; we merely alter the position of the decimal point.

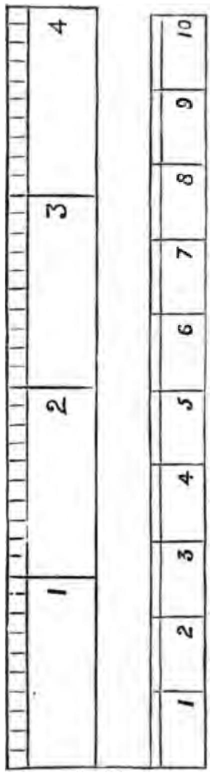

FIG. 2.

Experiment 3.—Cut a strip of cardboard an inch wide and $39\frac{3}{8}$ inches long, divide it into 10 equal parts, then divide each of these divisions into 10 equal parts, and your metre will be divided into centimetres. Now divide 1 decimetre into millimetres. If you do this carefully you will have a useful measure. Strips of cardboard with these measures and divisions can be bought for a small sum,

but we have advised the making of these samples for yourselves, that you may get a more thorough acquaintance with the divisions of the standard measures employed.

Experiment 4.—Draw a straight line on a board or on a sheet of paper, take its length accurately by each of your measures, in inches, and in centimetres, then compare the results by reduction; see that they agree. Draw a curve, then measure it by a piece of string, which afterwards measure by your standard.

Supposing you are requested to express 10 miles in kilometres—

1 mile = 1760 yards. 10 miles = 10 × 1760 yards.

$$\therefore \frac{1760 \times 10 \times 36}{1000 \times 39{\cdot}370} = 16{\cdot}09 \text{ kilometres.}$$

It may be of use to be able to refer to our Imperial measures of length in the French equivalent; we therefore give them—

1 inch, or $\frac{1}{36}$ of a yard	=	25·4 millimetres.
1 foot, or $\frac{1}{3}$ of a yard	=	3·048 decimetres.
The standard, 1 yard	=	·9144 metre.
1 pole, or $5\frac{1}{2}$ yards	=	5·03 metres.
1 furlong, or 220 yards	=	201·2 metres.
1 mile, or 1760 yards	=	1·609 kilometres.

1 kilometre = $1093\frac{3}{5}$ yards, or $\frac{5}{8}$ Eng. mile nearly.

The divisions of the metre are conveniently expressed—

1 decimetre	=	·1 metre.
1 centimetre	=	·01 metre.
1 millimetre	=	·001 metre.

The next measurement is that of area, which consists of two dimensions, and makes what in our table-books is called square measure.

Having mastered measures of length, square measure becomes easy.

Experiment 5.—Cut out a piece of cardboard exactly an inch long and an inch wide. You will have a square inch. Cut out a piece of cardboard exactly 1 cm. long and 1 cm. wide, and you have a square cm. After having cut each of these squares, put each side in turn along your standard measure, to see that they are accurate, as shown in Fig. 3.

Experiment 6.—To prove that 9 square feet make a square yard. Draw a straight line on a piece of

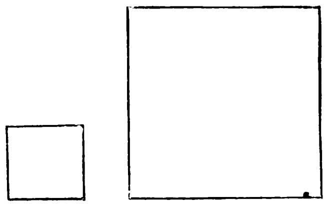

FIG. 3.

cardboard or stiff paper 3 inches long; let 1 inch in this case stand for 1 foot. Draw a line at right angles to this from one end of the line, make this line 3 inches long; now complete the square. Cut it out with a sharp knife or chisel. Divide one side into 3 equal parts, draw lines across from these points. Now divide one of the other sides into 3 equal parts, draw these lines across to the opposite side. You will have a series of squares if you have drawn them accurately, each one representing a square foot. Now number them from the left hand top corner and you will find you have 9, as shown in

Fig. 4. The standard English measure of surface is 1 Square yard.

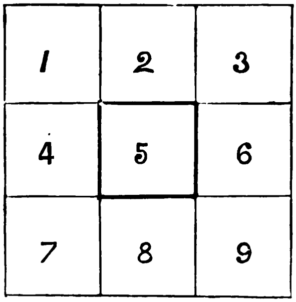

FIG. 4.

The standard in Metric measure is the square metre, = 1·196 sq. yards.

Length multiplied by breadth gives area, whichever standard we adopt.

We need not give the table for square measure in English, but in the Metric system it stands—

100 sq. millimetres	=	1 sq. centimetre.
100 sq. centimetres	=	1 sq. decimetre.
100 sq. decimetres	=	1 sq. metre.

So that—

1 sq. decimetre	=	·01 sq. metre.
1 sq. centimetre	=	·0001 sq. metre.
1 sq. millimetre	=	·000001 sq. metre.

Experiment 7.—Draw some figures contained by straight lines, measure them by means of your standard measure in English and decimal measures; express one in parts of the other.

Experiment 8.—Draw some areas, and divide

them into equal subdivisions by both English and French units of measurement. In drawing these figures you must use a set square, *i. e.* a triangular flat piece of hard wood, having one of its angles a right angle. Use it carefully, so that edges do not get notched.

The standard angle is the right angle. It is formed by one straight line drawn perpendicular to another straight line. To illustrate this—take a dish of water and a bullet attached to a cord; suspend the bullet so that it just dips under the surface of the water. The water will be horizontal, the cord to which the bullet is attached will be vertical, and the surface of the water will be at right angles to the cord. You must let the bullet hang quite free, not touching anything but the water.

Now we come to the measure of volume or capacity, called in our table-books cubic measure.

This is a measure of three dimensions. The standard in English is the Cubic yard. The standard in French is the cubic metre.

1728 cub. inches	=	1 cub. foot.
27 cub. feet	=	1 cub. yard = ·7645 cub. metre.

For capacity we use—

4 gills	=	1 pint.
2 pints	=	1 quart.
4 quarts	=	1 gallon.
6¼ gallons	=	1 cub. foot.

For capacity the French measure for liquids is the cubic decimetre, called 1 litre. If we compare the pint with the litre we find 1 pint = ·568 litre, and that 1 gallon = 4·544 litres. A cubic deci-

metre or litre contains about 61 cubic inches, and a quart about 69 cubic inches. A litre is a little more than $1\frac{3}{4}$ pints, more accurately, 1·7607 pints.

The French table of liquid measure runs thus—

10 centilitres	=	1 decilitre.
10 decilitres	=	1 litre.
10 litres	=	1 dekalitre.
10 dekalitres	=	1 hectolitre.
10 hectolitres	=	1 kilolitre.

Experiment 9.—Make a cubic inch by cutting

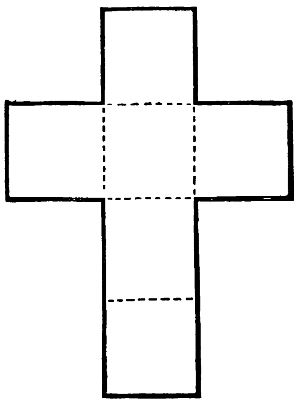

Fig. 5.

cardboard as shown in Fig. 5; also a litre by cutting cardboard in the same way, but each side to be a square decimetre. With a sharp knife partially cut the card through, along the lines that have to be folded; the edges will then be sharp and well defined. We may sometimes find bottles that hold the litre. Get one if you can; compare its size with the pint. If you are able to do this, get some dry sand, fill your litre box with it; then put it into a wide-

mouthed bottle. If a little too large to hold it exactly, put a mark round it, to show how much the litre of sand occupies. The bottle can then be emptied and wiped out, and its space replaced with liquid.

Experiment 10.—Get some cups of various sizes, some dry sand, some spoons of various sizes. Ascertain the size of a cup by the number of spoonfuls of sand you can put into it, then ascertain how many such cupfuls of sand are required to make a pint, a litre, a quart. Repeat the experiment by taking a different-sized spoon and the same cup, then secondly a larger or a smaller cup. Spoons and cups must be level full in each case. If this experiment of measurement is performed by several in the same class, let the results be compared. This may be varied in many ways. To bring out the measurements accurately, care and patience is required.

In making measurements string may be used, knotted at given intervals, so that the distance between the knots is a unit distance. In measuring curves, or from point to point, string may be used. The use of the tape-measure may also be introduced, and if you have a garden or field it is a good exercise to use the surveyors' chain of 22 yards, or the tape of the same length. The great use in a lesson of this kind is to impress on a student the importance of being accurate and reliable, and the exercises form an excellent introduction to the experiments which are to follow. This is perhaps not the most interesting chapter to begin with, but we wish to follow the order of subjects as given in the Code for Evening Schools; at the same time it is a most important subject.

LESSON II.

STANDARDS OF WEIGHT.

THE standard of English weight is one pound (lb.) avoirdupois, which consists of 7000 grains. The imperial standard pound consists of a cylinder of platinum 1·35 inches in height, and 1·15 inches in diameter. This is quite independent of our measures of length.

The French standard of weight is the kilogramme, and is the weight of a cubic decimetre of distilled water at 4° C., *i. e.* about 39° Fah. It was arranged from this as a standard because water is to be had anywhere, and at the temperature mentioned it has attained its greatest density. A platinum block was made to balance this cubic decimetre of water, and that has been put away in the Standards Department for the standard kilogramme. Now according to our cubic measure, 1000 centimetres make the cubic decimetre, therefore 1000 centimetres of distilled water make 1 kilogramme, and 1 centimetre = 1 gramme. The litre of distilled water is the same in both weight and volume as a kilogramme.

Now when we look at the subdivisions of the pound and kilogramme, we see the latter has the advantage over the former, in consequence of its

consisting of a number of regular, equal parts. We cannot say this of the pound avoirdupois, which has the following subdivisions—

16 drams	=	1 ounce (oz.).
16 ounces	=	1 pound (lb.).

Beyond these we take multiples of the pound to make up the quarter, cwt., ton.

Troy weight and Apothecaries' weight, which are very little used, have other subdivisions, but the grain is the same in all these weights—

7000 grains	=	1 lb. Av.
5760 „	=	1 lb. Troy.
437½ „	=	1 oz. Av.
480 „	=	1 oz. Troy.

Now let us look at the subdivisions of the kilogramme—

10 milligrammes (mg.)	=	1 centigramme.
10 centigrammes (cg.)	=	1 decigramme.
10 decigrammes (dg.)	=	1 gramme.
10 grammes (Gm.)	=	1 dekagramme.
10 dekagrammes (Dg.)	=	1 hectogramme.
10 hectogrammes (Hg.)	=	1 kilogramme.
10 kilogrammes (Kg.)	=	1 myriagramme (Mg.).

Now let us make one or two comparisons between English and French weights.

Take the gramme. It is equal to 15·4323487 grains, or, roughly, 1 gramme = 15½ grs.

1 kilogramme	=	2⅕ lbs. Av. = 15432·1 grains.
1000 kilogrammes	=	35 lbs. less than 1 ton.
and 1 ounce Av.	=	28·35 grammes.
1 ounce Troy	=	31·10 grammes.
1 grain	=	·0648 gramme.
1 lb. Av.	=	·4536 Kg.
1 cwt.	=	50·8 Kg.
1 ton	=	1·016 millier.

The following higher multiples of the kilogramme are in use, taking the place of our hundredweight and ton—

10 myriagrammes	=	1 quintal.
10 quintals	=	1 millier or tonnea.
1 English ton	=	1·016 millier.

With these comparative weights it will be easy, we think, for you to express a weight of one kind in terms of another. You will be able, for example, to find the value of 50 or 1000 kilogrammes in cwts. or tons, and the number of lbs. and ounces in a given number of grammes.

To work this practically, you must have some ordinary scales, and a set of English and gramme weights.

Experiment 11.—Take a 2-ounce weight, put it into one scale, put sand into the other till it balances exactly. Remove the 2-ounce weight and find the weight of the sand in grammes. Having gained this, calculate it arithmetically; see if your two results agree.

Note.—The authorized English abbreviation for gramme is "gm.," to distinguish it from "grain."

Experiment 12.—Make a cardboard cube, the inside of which shall be a cubic centimetre; cover the outside with thin sheet lead to make it water-tight. Balance it with shot, then put in a gramme weight, then water into the hollow centimetre. It ought to balance the gramme weight. Empty this out, fill it with hot water—it will not balance.

Experiment 13.—Weigh, in your hollow cubic centimetre, milk, tea, coffee, methylated spirit, glycerine, and you will find that none weigh exactly the gramme, all except the methylated spirit will weigh more than

the gramme. If you have weights representing subdivisions of the gramme, see how much more these substances weigh. Keep a record of your weighings.

Experiment 14.—Take a small thin glass beaker, balance it, put in some water, weigh it in grammes, and you have both volume and weight, for if it weighs 15 grammes, each gramme measures 1 cub. centimetre; therefore the volume will be 15 centimetres.

You must remember however that this only applies to water. In our lessons later on we deal with water as the standard of weight for liquids and solids.

Experiment 15.—After using the beaker for liquids let it be thoroughly dried and balanced; try some experiments in weighing some pounded solids.

Now we want you to turn your attention to the balance itself, to see how it is made, and why it is made so, and how it is that substances can be accurately weighed by using it. For many purposes of weighing, *e.g.* parcels at railway stations and letters, spring balances are used. These have to be tried and set by means of the ordinary balance, so we need not deal with them here, although you will find them useful in testing stresses and pulls when you have to represent such stresses in pounds.

Look at a balance, see what parts it consists of. The balance used by an ironmonger or grocer is not so delicate as that used by the chemist or the science teacher, but it consists of the same essential parts. You at once see there is the beam, the support for the beam, the pans hanging from each end of the beam.

Make a rough sketch of the balance you are looking at, attach the name to the various parts.

Experiment 16.—Take a smooth flat piece of thin

wood, about 12 inches long, and 1 inch wide (Fig. 6). Take its length accurately. Now draw a line across it, at half its length; next draw a line along it at exactly half the width; this line need only be half-inch or less long, it is merely to show the exact centre of the wood. Through this centre bore a hole large enough for a strong pin to pass through, turn it upon this several times, so that the wood moves easily about it as a centre. The slip of wood will now balance in any position about the pin, vertically, obliquely, or horizontally. That will not do for a scale beam, for when the beam comes to rest it must be horizontal. You can manage this with your slip of wood. Bore another hole, just above the last, but in the same line with it. Make the wood to turn as easily on the pin as in the last case. Now turn it about and let it come to rest; it will now always swing to the horizontal, and there remain. This is how the beam has to be hung, from a point a little above its centre, but instead of hanging it on a carpet pin, there is driven through it a hard steel pin, of a triangular shape, the smallest angle pointed downwards, so that whenever it rests, it is on a "knife-edge" only, so that the least weight on one side more than another makes it turn out of the horizontal.

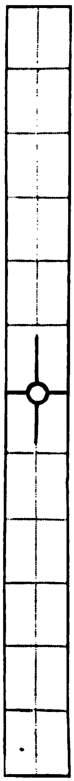

Fig. 6.

Experiment 17.—Suspend your slip of wood by twisting a piece of wire round the ends of the pin on both sides of the wood. Suspend a weight, say 2 ozs. or 3 ozs., at one end of the rod, take the opposite end

in your hand and press it downwards; by this means you lift the weight. Now instead of pressing at the end of the beam, press midway between the end and point of suspension. You will then have to push down harder than you did before to raise the weight.

In proof of this, put weights in place of your hand. If the weight at the end of the wood is 3 ozs., you will find that it will be balanced by a weight of 3 ozs. Now slip the 3-oz. weight midway between—where the hand was in the second case—leaving the other 3 ozs. at the end as before. They will not balance now. Keep adding weights, and you will find them balance when the midway weight is 6 ozs. This piece of wood acts as a machine called a lever, from a word which means "to lift." Whenever a crowbar is used to lift or push a load it is a lever. The scale-beam is a lever of the simplest form. The support of the lever, or the part on which it turns, is called the fulcrum. The ends from the fulcrum are called arms. The scale-beam has equal arms, therefore any weight at one end must have a corresponding equal weight at the other end to balance it. When the arms are unequal, then the weights will be inversely as the length of the arms, in order that they may balance.

Experiment 18.—Make this clear by your made lever. Divide each arm into 4 equal divisions. Make some little loops of thread to slip over the lever. To these attach some circular pieces of cardboard, suspended by three threads tied to little wire hooks like a scale-pan. Now put one at the end and one midway on the opposite side. Put 1-oz. weight in the scale at the end. See how much will

be required to balance it. You will find 2 ozs. will be required. Now shift this to the first division. You will see it will now require 4 ozs. here to balance 1 oz. at the end of the opposite arm. Shift the weights about and you will soon learn the principle of the first kind of lever.

Now we will describe the ordinary balance, as shown in Fig. 7. As we have said, the beam A B is

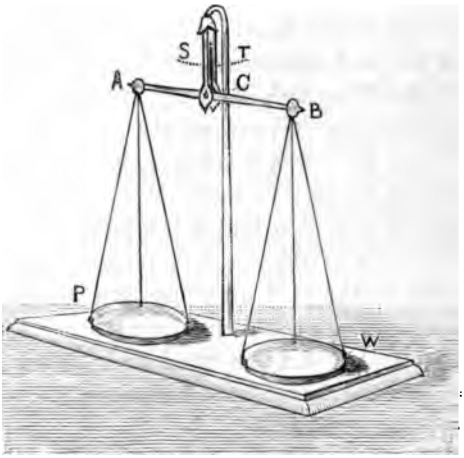

Fig. 7.

a lever of equal arms, and when at rest should hang horizontally, even without scale-pans. How this is managed we have already said. The fulcrum or support of this lever is a hard steel triangle, C. It rests on this sharp angle called a "knife-edge" in the fork S. In delicate balances the knife-edge rests on hard agate plates. Two scale-pans, P and W, of equal weight, are suspended from opposite ends of the beam. Attached to the centre of the beam, hidden by the fork, is a

delicate tongue of hard steel, fixed exactly at right angles to the beam. Should the beam move the least, so as to be down one end or the other, this tongue, T, points outwards on one side or another, according to the dip of the beam. At rest and in equilibrium the beam is horizontal, and the tongue perpendicular to the beam, hidden by the slit. All is now ready for use. Whether your scales are like those we have described or not, the following experiments can be tried.

The term "scales" is applied to the ordinary kind, while "balance" is the term used for the more delicate machines. Some balances turn at half-a-grain, others at one-ten-thousandth part of a grain, while the large scales for rough business would not even turn at half-ounce or an ounce. The large weighing-machines at railway stations or markets, where loads of hay, wagons, trucks, and steam-engines are weighed, are made with a combination of levers instead of one lever.

Experiment 19.—See that your balance hangs "true." Put a weight into one scale-pan, put some smaller weights into the other till the pans balance. Add together the smaller items. See that this sum agrees with the larger weight.

Put some small shot or sand into one scale-pan, balance it with marked weights. Take the sum of the weights, remove them; now put shot or sand into this pan till both pans balance. Take out the sand from the first pan and put in the weights that you removed from the first weighing, the pans should again balance. Try a series of experiments of this description.

Experiment 20.—Balance a small weight with a cubical block of wood neatly shaped and cut. Now replace it with a block of exactly the same size and shape, of a different wood; most likely the pans will not balance now. Take a third specimen of wood, then a cube of same size cut out of a potato, turnip, or soap. The results will prove most clearly that equal volumes of the different substances often have different weights. These and similar experiments with the balance, if accurately performed, will aid you in its further use in our later experiments.

LESSON III.

HOW A CANDLE BURNS.

FOR our first experiments we will take the study of a candle. The late Prof. Faraday gave a course of lectures on a candle to a juvenile audience at the Royal Institution during the Christmas holidays, 1860-1. In his opening remarks Prof. Faraday said: "There is no better, there is no more open door by which you can enter into the study of natural physical philosophy than by considering the phenomena of a candle. There is not a law under which any part of this universe is governed which does not come into play and is touched upon by these phenomena." Surely therefore, when borne out by such an authority, we do well to take for our first experiments such an interesting and instructive subject as a candle.

The making of candles forms a good subject for a lesson, but that is rather beside our subject. It is an advantage however to the teacher to have specimens of different kinds of candles at hand for reference, such as the dip, rush, wax, and paraffin.

Experiment 21.—Take a paraffin candle, let it be examined. It is solid, and a wick of twisted plaited cotton passes through it from end to end. These are

made 4, 6, or 8 to the pound. Take a "fours." Stand it up in the middle of a plate or saucer. Set light to the wick. Notice the wick, it curves outwards. If the air in the room is quite quiet, the flame is upright. Let all these little points be observed.

After a few minutes a little cup will be found round the wick. The edge of the cup will be solid, sharp, and well defined, much better in shape than could be cut with a tool. This cup gets bigger and bigger, till the conical end of the candle is all burnt away, and the cup is as big round as the shank of the candle. Ask any of the class to look carefully at this cup. The cup is not empty. What does it contain? The solid part of the candle has been melted. The flame, then, gives out heat as well as light.

Call to mind other instances of heat melting solids, like lead, zinc, iron, ice, and numberless others.

Blow out the candle-flame, the liquid in the cup cools, and becomes solid once more.

Re-light the candle. The cup soon becomes full of liquid, which climbs up the wick, and here it changes into gas and burns.

Note the three forms in which substances exist, viz., solid, liquid, and gas.

The candle is a miniature gas-works.

Experiment 22.—Fill the bowl of a long clay pipe with small coal, plaster it over with some softened pipe-clay or earth, so that it is quite air-tight. Now put the bowl into a fire (Fig. 8), or lamp-flame; fasten it, so that the stem of the pipe is steady. Notice what comes from the tip of the stem after a short time. Set light to whatever comes out; it soon burns as steadily as the candle burns. This gas from the pipe

burns without a wick. Why must the candle have a wick? Allow the pipe afterwards to cool, break the bowl, notice what is left behind. Coke. What is left behind of the candle? Why this difference?

Have gas-burners wicks?

FIG. 8.

Experiment 23.—To answer the question—How is the liquid raised from the candle cup into the wick?

Take three small glasses—wine-glasses will do. Place them side by side, two of them raised on blocks so as to stand one above another as in Fig. 9. Take some threads of darning cotton, twist them together, cut off lengths to reach from glass one to two, and

from two to three, with enough to have a small coil at the bottom of the glass in each case. Put some coloured water in the lowest glass, well moisten the strands of cotton, place each as shown in the figure. Observe what takes place. How has the lower glass got emptied so soon? Water, if poured, never runs upwards! This water has; for it has gone from the bottom glass to the highest.

This reminds us of how the wicks of lamps act. The liquid oil is lifted out of the holder to the upper part of the wick; it is there burnt as in the candle-flame.

FIG. 9.

Moisture is raised from the soil through the stem of a plant into its branches and leaves.

Experiment 24.—Get some pieces of glass tubing of different sizes, some pieces of very small bore, like thermometer tubing. Cut them into lengths of about 4 inches each. You can easily cut them by means of a triangular file. Give the tubes a sharp scratch or cut where they are to be broken off; then take the tube in both hands, the scratch on the glass between the thumbs; give a sharp jerk upwards, and the tube will be broken. The rough edges can either be held in a lamp-flame till red-hot, so as to melt down the roughness, in which case they must cool very gradually, or they can be smoothed off with a file. Cut

a strip of stiff cardboard to make a stand for them, as in Fig. 10. Bend the card so that the middle portion, having holes punched or bored, will allow the tubes to go through, and at the same time steady them; the two ends must be cut so as to widen out to form feet. Now take the lid of an earthen pot, turn it up so as to form a trough, in which the bottom of the set of tubes can dip. Run some water through the tubes to be sure they are clean. Pour in the trough

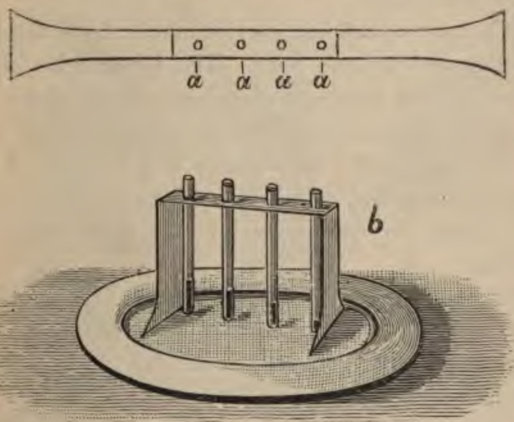

FIG. 10.

some clear, coloured liquid. Stand the tubes in. The liquid will rise above the level of that in the trough, and not to the same height in all, but highest in that tube with narrowest bore. Let this result be well observed. Then let the tubes be cleaned and put away for next time. Fig. 10 represents the tubes as standing in a plate.

Experiment 25.—The last experiment can be modified. Have two pieces of thin glass cut just

large enough to stand in the box-lid trough used in the last experiment; let them be thoroughly cleaned with soap and water, then rinsed with cold water. Put them face to face, set open the edges on one side with a small wedge of wood—the end of a wooden match will do. The upper and lower edges will form a V. Set the fixed plates upright into coloured water; presently the water will rise highest in that part where the plates come close together, and lowest at the wider edge.

This proves that liquids rise much above the level in tubes of very fine bore. The inner sides of the plates act as sections of tubes. Make these two pieces of apparatus neatly, and keep them for these experiments only. The plates may be made 4 or 6 inches square, and stood in a plàte or saucer. That is a matter for each experimenter to determine for himself.

The name given to this force that lifts liquids in these fine tubes is "capillarity," from *capillus*, a hair, because the action is seen most strikingly in fine or hair-like tubes.

A bundle of cotton in the candle or the lamp-wick consists of a large number of fine tubes, very closely packed side by side. Examine the wick of a rush candle, the tube is rather coarse there.

Experiment 26.—Cut a small pillar of salt, about 2 inches square and 6 inches high. In cutting salt, use a large dinner knife like a saw, not putting on too much pressure, or you will break the salt irregularly. Take a jug holding about a pint of water, dissolve salt in the water, then colour it with some red or blue ink. Stand the block of salt in the middle of a

plate or saucer (Fig. 11), pour in the liquid; it will rise in the block, its height being shown by the colour. This was a favourite experiment of Prof. Faraday, in which he considered the plate to be the candle, and the salt the wick, and the solution the melted tallow, remarking as he did it—"If the coloured solution were combustible, it would burn as it entered into the wick."

Experiment 27.—Cut a piece of cane about an inch

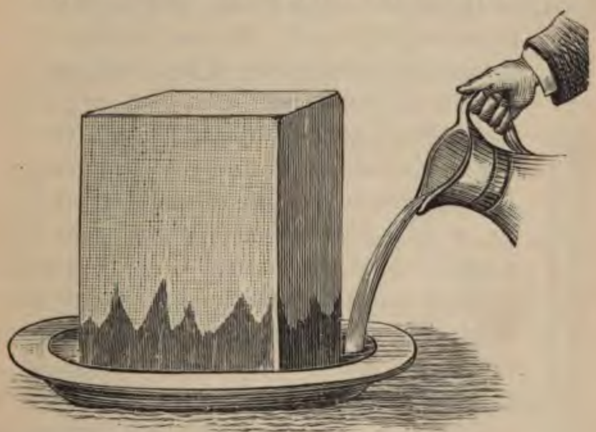

Fig. 11.

and half long, the bottom edge flat, so that it can stand up in the middle of a saucer or upturned box-lid, in which a little paraffin oil has been poured. In a short time the oil will have risen to the top of the cane, and may be lighted, and will burn till the oil is exhausted.

The use of blotting-paper, the use of the towel in wiping the hands, loaf-sugar licking up drops of water, are all instances of this capillary attraction.

Experiment 28.—Take a short piece of candle, light it, stand it in a plate, the bottom of which is just covered with water. Now stand in the plate—enclosing the candle—a lamp-chimney. The light goes out. Re-light the candle. Repeat the experiment; the result is the same. Re-light the candle once more. Now hold the lamp-glass just a little above the water in the plate. The candle goes on burning. Stand the glass on some little blocks, so that its lower rim is just above the water. When the candle is burning vigorously, slip over the top of the chimney a stout piece of flat cardboard, or a piece of slate. Now what happens? The candle-flame goes out again. Why is this?

FIG. 12.

Experiment 29.—Re-light the candle. Having provided a piece of cardboard or light tin, a little bigger than a penny piece, bore a small hole in the centre. Cut, with scissors or chisel, across towards the centre, some slits, to within a quarter of an inch of the centre; turn these sections up, like the vanes of a mill. Pass through the centre a fine wire or a knotted thread; the vane will balance if you have prepared it carefully. Now hold it above the chimney-glass in which the candle is burning. The vane will revolve rapidly. By a little contrivance, a wire may be fixed on a chimney-glass to carry this vane (as in Fig. 12); it is an improvement on holding it by a thread.

Experiment 30.—Twist some threads of cotton round the end of a fine wire about 18 or 20 inches long. Saturate the cotton ball so formed with methylated spirit and set light to it. Notice the flame is upright.

Now lower it into a wide-mouthed glass—a pickle-bottle will do; the flame, although large and fierce, is extinguished almost at once.

These experiments carefully performed, talked over, and thought out, will form enough for one lesson. It is important that every little thing mentioned in the experiments should be attended to, and the questions put be answered by the experiments themselves. From these experiments we have learnt that—

1. The solid candle changes into a gas before it burns.

2. That substances like coal give off gas on being heated.

3. That the flame is confined to the wick of a candle.

4. That a wick consists of a bundle of very fine tubes, and that liquids rise highest in the smallest tubes.

5. That to burn gas directly no wick is required.

6. Capillarity is the name given to that which raises liquids in fine tubes.

7. That a flame will not burn without air, nor unless it can have fresh air.

8. That the flame heats the air all round it, and that heated air rises, and that the cool air at once fills the place of the rising air.

9. That this "upward current" of air causes the flame to point upwards.

LESSON IV.

WHAT HAPPENS WHEN SUBSTANCES BURN.

EXPERIMENT 31.—Take three small tapers, such as are used on Christmas-trees, or even wax vestas will do. Take also a strip of stiff wire about a foot long, and three short lengths of thin wire; twist one of these round each of the tapers and fasten them to the central wire, so that they branch out from it. Twist the lower end of the stiff wire into a ring, so as to form a foot (Fig. 13). Provide yourself with a wide-mouthed pickle-bottle. Light the tapers, which must not be placed directly under each other; when well alight, turn the pickle-jar upside down, and place it over the burning tapers. The flame of the topmost taper is extinguished first. Explain why this is, from experiments shown during the last lesson.

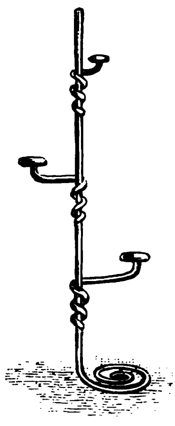

FIG. 13.

Experiment 32.—This is to answer a question about the candle which must have been in the minds of most of the class, especially when the bowl of the tobacco-pipe was broken, and the hard coke found

in it, turning their thoughts from that to the candle. Is the candle when burnt, destroyed? Where are the solid stick of paraffin and the wick gone to? Hold a dry tumbler glass, mouth downwards, over the candle-flame for a few seconds. A plain thin tumbler is best for this experiment. What happens? Is the glass as clear and bright as it was before? Wipe the inside of the glass with the finger. It feels moist; the streak made by the finger is plainly seen. Wipe out the tumbler dry once more; repeat the experiment. Moisture will form on the inside of the glass again. If convenient put a piece of ice on the outside of the glass, moisture will form faster. Do not confound the inside moisture with any that collects outside formed from the ice.

How does the moisture come inside the glass when it is held over a hot candle-flame?

Experiment 33.—For this you want a stiff card, large enough to cover the mouth of the tumbler, also some lime-water.

As lime-water may be required frequently, it is just as well if we tell you how to make it, and how to keep a stock of it. Take a lump of chalk, put it into a clear fire, see that it gets red-hot, let it remain so till it begins to crumble. Take it out of the fire with a piece of bent wire or a pair of tongs, put it on the top of the stove till it cools. This is quick-lime. Now put it on a dish, pour on it some cold water; bubbling, hissing, and boiling will take place, the lime swells and crumbles. Put it into a wide-mouthed bottle, fill up with water, close it by holding the fleshy part of the hand over the mouth, turn it over once or twice, then let it settle. The lime will go to the

bottom, the water above which will soon become quite clear; pour off some of this into another bottle for use—this is lime-water. When you take out a supply, fill the bottle up again with water, and stand it aside till you require some more of it. You can go on in this way till all the lime is dissolved, which will be a good many years, unless you use a large quantity frequently.

Should this solution turn cloudy at any time, filter it before using. Do not use ordinary blotting-paper for the filtering, but get a packet of "filter-papers," these will only cost a few pence.

With the candle and tumbler repeat Experiment 32. Cover the slip of card over the mouth of the tumbler as you remove it from the candle-flame. Turn it up quickly, pour in a little lime-water, shake it up—the lime-water will become turbid and cloudy.

Nothing could be seen in the glass to change the lime-water.

Take a second tumbler, as much like the last as possible, pour in some lime-water, and shake it up. No cloudiness comes in this. The change produced in the lime-water in the first tumbler must evidently have been caused from what was caught over the candle-flame as it was burning.

Experiment 34. — Take another clean tumbler, pour into it a little lime-water. Hold it up to the light, to be sure that it is quite clear. Take a piece of clean glass tubing, or tobacco-pipe, and blow (*i. e.* breathe) through the tube into the water. It again becomes turbid and cloudy.

Experiment 35.—Take a small bottle of soda-

water and another clean tumbler. Cut a piece of paper and fold it into a sort of hood to cover about one-half the mouth of the tumbler, as in Fig. 14.

Open the soda-water bottle, hold it so that none of the water goes into the tumbler. When its violence is off, hold the neck of the bottle slightly inclined under the hood over the mouth of the tumbler, as in Fig. 14, for a few seconds—do not allow any liquid to go in. Remove the bottle, cover a card over the

FIG. 14.

mouth of the tumbler, then pour in a little lime-water. Shake it up, and it will turn milky as in the other cases.

Experiment 36.—Take a seidlitz-powder, put the powders out of the blue and white papers into a dry, wide-mouthed bottle. Shake them well together, so that the powders get thoroughly mixed; no action takes place.

Now pour some water on the mixture: a great

bubbling starts at once. When this commotion has gone on for a short time, light a match, plunge it into the bottle: the light will be extinguished. Relight and hold the match, till it is put out when even at the mouth of the bottle. Take a tumbler as before, hold the paper hood over and tilt the mouth of the bottle to the mouth of the tumbler. Hold it there for a few seconds, then cover up the tumbler. Test it with lime-water; see that the result is as before.

Experiment 37.—Take another tumbler, pour from the seidlitz-powder glass in the same way, cover it up, light a match and put it into the tumbler: the flame will be extinguished. Uncover the tumbler, turn it bottom upwards for a short time, then try the lighted match again: now it will burn. These experiments show that the same substance that extinguishes the flame turns the lime-water milky, and that, whatever it is, it is heavier than air, because you are able to pour it from glass to glass, or on to the floor, and that it is invisible all the time, you only getting to know of its presence by the tests of lime-water and burning match.

Experiment 38.—Set light to a piece of wood, paper, a little straw, or anything that will easily burn, hold a clean tumbler glass over it, and use the lime-water test, and see if the results are the same as with the candle. Then take a petroleum, benzoline, or spirit-lamp, test with clean tumbler and lime-water as before; then try the same experiment with an ordinary gas-jet, using a small flame, or with the tobacco-pipe and small coal, as in Experiment 22. Compare all these results.

Experiment 39.—Take a lighted candle. When burning vigorously bring flat down into the flame a piece of card. The card will be blackened; if held for a short time it will be covered with a thick layer of black soot. Where does this solid black substance come from?

Experiment 40.—This is a little more elaborate, and requires a little care in fitting up. First you want a lamp-chimney, as in Fig. 15, a good sound cork, such as may be had from a pickle-bottle, to fit end *a*. Fit a small tube into the cork, as at *b*, bore several holes through the cork, or cut some big notches round the end of the cork. The holes can be bored with a rat-tailed file, the notches cut with a sharp knife. These holes are to supply air to the burning taper in the experiment. At the top of the glass you must provide a little cage, either by cutting a piece of wire-gauze or a piece of perforated zinc, to fit the inside of the tube about an inch and half from the top. This can be held in its place by some short lengths of thin iron wire, as in Fig. 15, *c*. Some wire must also be twisted round the chimney so as to meet in a loop at the top, so that it can be hung up like a lantern.

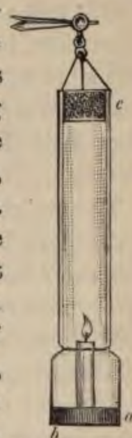

FIG. 15.—Lamp chimney for collecting products of combustion.

Next provide yourself with a pair of scales—small apothecaries' scales will do—a pair with box, weights, and glass pans can be bought for 3*s.* 6*d.* Make a stand about 12 inches high on which to hang them. Remove one of the pans and suspend the chimney in

its place. You must also provide yourself with some fresh caustic potash—1 oz. will do; handle it only with a dry hand, and then as little as possible. Break it up in small pieces about the size of a pea, and fill the upper cage in the chimney with it. Now balance it by putting weights into the scale at the opposite end of the beam. All is then ready for the experiment. Arriving at this stage, take out the taper, light it, put it back into the chimney. Be sure that it again balances the weights. After burning a short time, it will become heavier—something therefore must have been added to the chimney side of the load. Where does this extra weight come from? How is it that a candle becomes heavier by being burnt?

The substances that make up the candle join themselves to one of the gases in the air, and it is this extra substance that it takes from the air that gives extra weight. The new substances formed are caught by the caustic potash. Water is one of the substances, as you saw when holding the tumbler over the flame: this moisture the potash absorbs. The other substance is that which spoilt the look of the lime-water, and is called carbonic acid gas, like that from the seidlitz-powder and soda-water, and this the caustic potash absorbs: these two together add to the weight. We learn therefore—

1. That substances are indestructible. When a candle burns, its substances are not really destroyed, but they mix with a gas in the air which we call oxygen, and form water and carbonic acid gas. This goes on till nothing of the solid candle remains.

2. That if the candle has not enough air to carry

on the burning properly it smokes and smells, and soot settles on a piece of card or anything put to catch it.

3. That the wick of the candle is charred bit by bit, and is carried away into the air.

4. That no real burning can take place without the burning substance combines with the oxygen of the air.

5. That the process of union between these substances gives out the light and heat, causing the flame.

6. Similar changes take place when any other ordinary substances burn.

7. These changes are called chemical changes, because new substances are formed by the union of those that burn and the oxygen in the air.

This lesson may be a little more difficult to the beginner than the last, but a good teacher or an appeal to a book on Chemistry will put the matter quite clear. In another lesson, when we refer to the air and what it contains, we shall have more to say about oxygen.

All the experiments mentioned in this chapter should be carefully performed before going to the next lesson.

LESSON V.

THE FORM OF FLAME.

Experiment 41.—Light a candle, let it remain till it has a good steady flame. Look well at the form of the flame. It appears to be a shell of light and not a solid. Provide yourself with a piece of very thin glass or a piece of talc, bring it down horizontally on to the flame. You can then look into the flame. On bringing up the glass you will have an imperfect ring on the glass formed by the soot.

Experiment 42.—Take a ball of cotton, attach it to a wire, saturate it with methylated spirit, light it, hold it steady, bring down upon the point of the flame the glass, as in the last experiment. You will see a hollow ring of flame. Blow out the flame, a ring of charred cotton will encircle a clean patch, showing that inside the outer shell there was no flame.

Experiment 43.—Get a fine piece of glass tubing between 4 and 6 inches long. Hold the centre of the tube in a lamp-flame till the glass is soft, then remove it, and bend the tube as shown in Fig. 16. Hold it above the flame so that it may cool gradually. Now place one end through the shell of flame, as in Fig. 16, a thick vapour will soon rush out of the other

end of the tube: this vapour may be lighted. This shows that the inside of the shell of flame contains the material ready for burning, but it cannot burn because no air can get to it. To perform this experiment successfully, the tube must be of small bore, and it must be held steadily. As it may get hot if used for some time, twist a piece of wire round it, by which you can hold the tube.

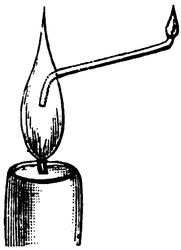

FIG. 16.—Bent tube for burning gas inside outer flame.

Sketch the flame on the board for the benefit of the class, or if you are studying by yourself, draw it on paper. The outer cone (*c*, Fig. 17) is that portion where the substance is completely burnt, but from which we get little or no light; the second underlayer is where burning goes on imperfectly (*b*), but where the vapour and solid are heated white-hot, and so give out light, and from which you get the soot deposited when you put in the cardboard. The innermost portion (*a*) gives out no light, because being deprived of air—the air being shut out by the outer shell—it consists of dark and unburnt gas, and looks black around the wick.

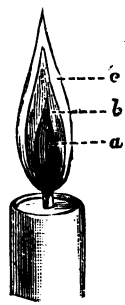

FIG. 17.—Candle-flame showing cones of combustion.

Experiment 44.—Repeat the last experiment with the flame of a spirit-lamp or a gas-burner: in each case you will find the result the same.

Experiment 45.—For this purpose you require a **Bunsen burner**, which consists of a small gas-burner

(Fig. 18); around this a metal tube is fixed, at the lower part of which, and on a level with the burner, tubes are provided, so that air can pass freely in. Over this a larger tube turns, so that the holes into the tube may be opened or closed as may be required. When the holes are closed the flame is bright, when open the flame is colourless, but gives out an immense amount of heat, because the burning is complete. This heat-producing power of the Bunsen makes it of immense value in the laboratory. So much more heat can be obtained from it than from an ordinary

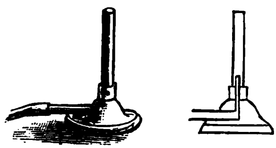

Fig. 18.—Bunsen's burner, and section showing admission of air to the flame.

burner, and no soot is deposited by it, because the burning is complete. Experiments 24 and 25 can be very nicely performed with the Bunsen burner. These experiments on the hollowness of flame can be carried still further.

Experiment 46.—Provide a tin saucer—a patty tin will do—warm it, put in a little methylated spirit, and set light to it. Watch the form of flame: it will be an irregular pointed cone, or if there are any draughts in the room it will be tongued, *i. e.* have several points. Hold in the flame across the saucer a stick of cardboard or wood; this will only be charred and burnt at the two points where it cuts the outer film of flame. Between these points

it will be clean and quite untouched. When this has burnt out let the saucer cool down—and having provided yourself with a small pill-box, a pinch of fine gunpowder, a little ether—a dessert-spoonful will do—and a tube with a funnel at one end, or one to which you can fix a paper or card funnel. Now the object of the experiment is to enable you to put the gunpowder into the pill-box during the time it stands in the midst of the flame. If well done it

FIG. 19.—Hollowness of flame.

will not be fired, but can be fired after the flame has burnt out.

Have all things in readiness: the powder screwed up in a piece of paper, just the quantity to be used, place the pill-box in the saucer, pour in the ether, set fire to it, place one end of the tube in the pill-box, shoot the gunpowder into the funnel, let it slide down the tube into the box, then withdraw the tube. While dropping the powder through the tube, hold the funnel end away from your face. Do it slowly and

carefully; if you do it in a hurry, or with fear, you are likely to bring some grains of powder in contact with the flame, then all will be fired. When the flame has died out, leave the powder a little time to dry, then apply a lighted match and fire it. The arrangements for the experiment are shown in Fig. 19. The experiment ought conclusively to prove that flame is hollow.

Before putting away the saucer perform the following experiment. Put in a little methylated spirit, warm it, and set it on fire. When burning vigorously, cover it up with a piece of board, or a woollen cloth: it will be extinguished at once.

Again: take the cotton ball, put on some spirit and light it; take a cloth in your hand and grasp firmly the flame: it will be at once extinguished.

Remembering these experiments, we may have a chance of extinguishing flame caused by accident, as from a broken lamp, a dress on fire, or any such sudden occurrence. In a case of a dress catching fire, be careful that whatever is used as a wrap must be tightly wrapped.

Experiment 47.—Light a candle, let it burn well, so as to be thoroughly well alight, then blow out the flame; hold a lighted match a short distance from it. The hot vapour will come in contact with the flame of the match, and the flame will travel to the candle-wick, which will be re-lighted. Repeat the experiment, but before holding the lighted match as before, let the vapour get cold: it will not re-light.

Now twist up a coil of iron wire round a pencil, bring this coil into the flame of a lighted candle: the flame will be extinguished, for the metal will take

away the heat, and cool down the vapour so much that it will be reduced below the burning-point. The temperature at which gas takes fire is called the ignition-point. Most gases have low ignition-points, at the same time a certain temperature must be reached before they will burn.

Experiment 48.—For this experiment you require a piece of fine wire gauze, about 6 inches square. Light a candle; when it is burning well bring down flat on it the wire gauze: the upper half of the flame will be extinguished, but the unburnt gas will pass through the meshes of the gauze, and if a lighted match be brought near to it, it will re-light. Repeat this experiment with a spirit-lamp or a Bunsen burner. It can be much more effectively done than with the candle-flame, in consequence of the latter being so small.

Experiment 49.—Take a small piece of camphor, put it in the centre of your wire gauze, set light to it. It will burn with a very smoky flame, but the flame will not pass through the meshes of the gauze, although the heated vapour of the camphor will do so. Set light to the vapour below the gauze, and blow out the flame above: it will cease to burn above but continue to burn below.

Why is it that the flame will not travel through, and set light to the gas on the other side? Because the metal in the gauze is a good carrier of heat, which it withdraws from the flame, and cools the gas down below the temperature at which it can burn.

This can be shown more strikingly still by—

Experiment 50.—Set light to some methylated spirit in a cup; while burning, pour it through the

wire gauze into a plate below. The spirit will pass through, but the flame will be extinguished as it passes through. The experiment furnishes us with the key to the use of the Davy lamp as a safety-lamp in coal-pits. The Davy lamp, if you look at it, or a drawing of it (Fig. 20), you will see is an ordinary oil lamp, with a hollow coil of wire gauze around it. The light inside the lamp is the flame that is unable to pass through to ignite the inflammable gas on the outside which is escaping from the seams of coal.

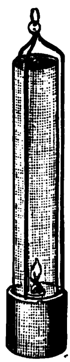

FIG. 20.

From this lesson we learn—

1. That flame is hollow.

2. That a candle-flame consists of three shells—the innermost is dark, not burning, and gives no light; the second shell gives out light and heat; the outermost is in a condition of complete burning.

3. The Bunsen can give us a colourless, hot flame by the admission of air into the flame.

4. That gases and vapours must reach a certain temperature before they will ignite.

5. That metals brought into contact with flame can extinguish it, by reducing the temperature below the ignition-point.

LESSON VI.

SOME PROPERTIES OF AIR.

In our former lessons we have seen that a candle cannot burn unless it can be supplied with air. We have also learnt that no substance will burn if the air is shut out away from it. Air is necessary for fire and flame, it is also necessary for life. We cannot live without being constantly supplied with air. We cannot be healthy and well unless we can have fresh air.

In this lesson, then, we shall have some experiments of another kind with air, so that we can learn something about it. You must look upon trying an experiment with air as asking the air a question: it gives you the answer by its action. The proverb tells us that "actions speak louder than words," therefore if you perform your experiments properly, you will get very distinct answers.

To begin with—Is the air a substance?

Experiment 51.—Take a paper bag, screw up its mouth, blow into it: it swells up more for every puff of air you put into it. When full twist up the neck of the bag, and you feel it is full of something. What is this something? Surely it must be air that you

have blown into it. Beat a smooth table with it, you seem to have quite a hard substance.

Now prick a little hole in the bag and press it: a puff of air will come out, which you can feel if you put it near your face. If held near a lighted candle and pressed rather hard, a sufficient puff will come out to extinguish the flame. If you arrange a little windmill of paper sails mounted on straws, you can turn it round rapidly from puffs of air from the paper bag. This shows that the air is a substance. The mere waving the hand, or moving a fan in it proves it. But we sometimes like to see the simplest things proved. It sets us thinking, and common simple things often teach us the finest lessons.

To show these experiments well, get a bladder from a butcher, trim up the neck, wash it in warm water, fit a glass tube to the mouth, and keep it for this and similar experiments. When it is dry, blow it up, tie up the neck, and rub a little oil well into it, it will preserve it. Coloured india-rubber bags can also be used for blowing up; they are easily obtained, and will keep a long time, and are perhaps better than the bladder in some respects; they are not however quite so strong.

That air is a substance, and exists all round us everywhere, may be shown in another pleasing manner, as in the next experiment.

Experiment 52.—Take a piece of thin cardboard, cut it into shape as in Fig. 21, make it about 4 inches × 2 inches, cut off the corners. Cut another piece of the same size. Now cut a piece of wood about 2 inches long and $\frac{1}{4}$ of an inch square, slit it down a little way at each end—be careful not to split

the wood further than about $\frac{3}{8}$ of an inch. Bore a hole through the wood in the centre as shown at *b*. Do this from both sides, so that the holes cross each other; this can be done by heating a piece of iron wire red-hot and burning the hole through. With a little strong gum or glue fix the cardboard into the ends of the wood: you will then have the vane as at *c*, so that you can twist it round on a shawl-pin, with either the broad or the narrow edge to the air.

When twisted with the narrow edge outwards to

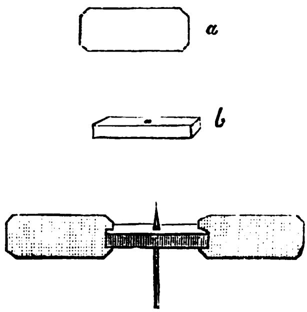

FIG. 21.—Vane to show presence of air.
a, cardboard piece; *b*, central wooden stem.

the air, it will go round for a much longer time, with the same energy of twist given it, than when the broad side is placed to the air. This shows clearly that the air offers resistance to a moving object. You find a considerable difference in moving against the air or the air moving against you, when you have to carry an open umbrella, and when you can carry the same umbrella closed. A similar result is obtained in—

Experiment 53.—Take a piece of thin paper, cut

it into two equal parts, spread them out, and drop them from the same height to the floor. Both pieces flutter about and fall slowly. When they reach the ground pick them up again, roll one of the pieces into a ball, as small as you can squeeze it. Now let the pieces fall from the same height: the piece with the smallest surface will reach the ground first—the paper ball will fall quite quickly. Both pieces are however of the same weight they were before.

Experiment 54.—Cut a sheet of thin paper into a circle about a foot in diameter, fold it first across the centre, then again across the centre, so that from the

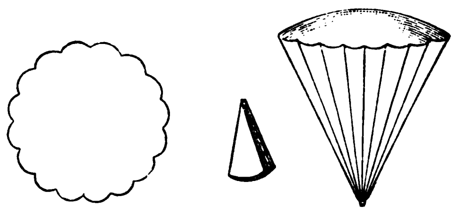

FIG. 22.—Parachute in parts and complete.

half circle the second folding will bring it into quarters, and these once again, bringing them into eighths, as in Fig. 22. Then with scissors cut the curve at the edge; attach to each of these a thread 18 inches long. Knot them together, and roll round the knot a piece of thin sheet-lead, such as chocolate is wrapped in. Now throw up the paper folded as we have described. After rising as high as it can, it begins to fall, opening out, and coming down very slowly—you have a miniature parachute. Its comparatively slow journey downwards is of course explained by the last experiment.

Experiment 55.—Take a penny piece, and cut a piece of thin paper the same size as the coin. Drop both paper and coin, side by side, at the same instant, from the same height. The coin gets to the ground first, its fall is direct and straight to the ground, the paper flutters about. Now place the paper on the top of the coin—be sure you do this without sticking them together—then let them fall. They will reach the ground at the same time. Repeat this experiment: it is a modification of Newton's celebrated "guinea and feather" experiment, only instead of using an air-pump for withdrawing the air, the coin clears it out of the path of the paper.

You have noticed a bird when it wants to fall closes its wings, but when it wants to mount it alternately spreads and closes them.

Experiment 56.—Take a wine-glass and a tumbler larger round than the wine-glass, partially fill the tumbler with water, float on its surface a cork. Invert the wine-glass and force it downwards into the water. The air in the glass will keep the water out. If you use two larger glasses in this experiment, you can place a small lighted taper on a floating cork in the outer glass (Fig. 24): the taper will burn long enough to show that the water only rises a very short distance in the inverted glass.

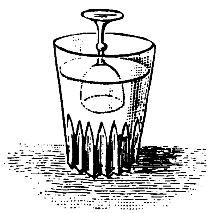

FIG. 23.

This shows clearly enough that wherever the air is, nothing else can be at the same time. "No two things can occupy the same space at the same time"

is one of the first laws of science we have to learn, and this law goes by the name "impenetrability." When a glass or any other vessel under ordinary circumstances is said to be empty, it is really full of air. The diver's dress and the diving-bell are made on this principle.

Experiment 57.—Take a wide glass and the wine-glass, as in the last experiment. Put some water into the wide glass, now push the wine-glass mouth downwards as before, tilt it a little on one side: some bubbles will escape, rushing upwards through the water. Continue this for some little time: as the air gets out of the glass the water gets in. This shows us that air is lighter than water, also that we cannot keep spaces empty unless we make very special provisions for doing so. "Air lighter than water!" we fancy we hear some young folks, who now see this experiment for the first time. "Does air weigh anything at all? I thought it could not weigh anything! It seems so light." It weighs more than young people think it does. More of this later on.

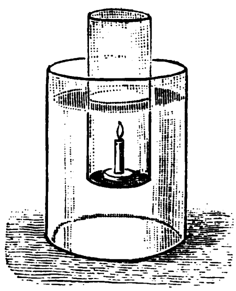

FIG. 24.

Let us go back to Experiment 56. Perform it again very carefully. Let us ask ourselves this question: Did no water enter the inner glass which is upside down? No air came out as in the last experiment. Yet look, the water has risen just a little bit. Why is this? Because the water has squeezed the air back into a smaller space. If you have an india-

rubber ball full of air you can flatten it by squeezing it; take off the squeeze and it comes out again plump and round. The air in the glass would be pushed into a very small space if you were to put it into a glass of water 100 feet deep.

Experiment 58.—Take a pop-gun, fit to it two good plugs, put one in at one end of the barrel, then with the stick force in the other. Notice how great the resistance is after a short time. At last the squeeze on the imprisoned air becomes so great, that in its struggle to be free to occupy its old space the plug is driven out with considerable force. Make a drawing, such as in Fig. 25, which shows the part of the barrel occupied by the air. We learn from this experiment that the air is very elastic.

FIG. 25. Pop-gun.

The football is filled with air, because the air is elastic; cushions and invalid-beds are filled with air for this reason. Air-engines and air-guns act by compressed air.

The elasticity of air may be shown in another way, as in—

Experiment 59.—Put a small quantity of air in a bag or in a bladder, as mentioned in Experiment 51. Tie up the mouth securely and put it in front of the fire, so that it can gradually become warm. When first put down there may be so little air in it that it will look shrivelled. As it becomes warm it will become bigger and look more plump, in fact it may get so plump that it may burst, if allowed to get very warm. Remove it and allow it to cool—the bag shrivels down again.

Experiment 60.—We will take another illustration of this. Take a flask—a common oil flask will do—clean it with soda and water, then rinse it well with warm water, then with cold water two or three times. Put sufficient water in it so that when turned mouth downwards in a tumbler containing a little water it may look as in Fig. 26, the water standing above that in the tumbler. Twist up a piece of paper, light it, so that you have a tolerably good flame. Hold the flame to the upper part of the flask for a short time—but keep the flame moving—the liquid will be forced downwards by the air in the bulb of the flask expanding. Remove the flame to allow the flask to cool: the air shrinks back to its old space, and the liquid rises to its former height. If you use a bulb with a very small tube for this experiment, the warmth of the hand is enough to show it very effectively. A spirit-lamp may with advantage be used instead of the burning paper.

Fig. 26.

This teaches us that air is expanded by warmth, and that it is very sensitive to differences of warmth. The least increase of temperature increases the air volume, and the least decrease lessens the volume. Air is very elastic. If you take the same volumes of warm air and cold air, the colder will be heavier. It is this uneven heating of the air that causes winds.

We have used the terms warm and cold simply

as points of comparison at present. We may have to ask our experimenters to learn what temperature means presently. From this lesson we learn—

1. That air is a substance.

2. That air is very elastic, it shrinks into a smaller space when squeezed or when cooled: that it takes up a larger space when heated.

3. That when it moves it gives motion to other objects like windmills, and when squeezed air is loosened suddenly it drives objects with great force, as in the air-gun.

LESSON VII.

HOW AIR IS WEIGHED.

In our last lesson our experiments clearly proved that the air is a substance. In this lesson we will take a few experiments proving that "the air has weight."

From experiments in our last lesson we saw that warm air is lighter than cold air, and in the air that we call the "earth's envelope" we have layers of different warmths, which move about because of this, and so cause winds. A wind is air in motion.

Experiment 61.—Blow a soap-bubble; see how it acts. If it is blown in a warm room it falls to the floor quickly; if however you take it out into the open, it is very likely to rise, because the air from the mouth is warmer, and therefore lighter. Even the two together, the soap-film and warm air, weigh less than the same volume of cold outside air, therefore it floats. Here we have air floating in air. The bubble can be filled with air from a pair of bellows, by fastening the tube from which the bubble is blown to the mouth of the bellows with a piece of india-rubber tubing. As a soap-bubble is of great use in many experiments, we give a recipe for a mixture we have found good for this purpose in the Appendix.

Experiment 62.—Blow a bubble by attaching the tube to a gas-pipe, turn the gas on very gradually. The bubble will not get very large before it will tear itself away from the pipe, making a hasty leap upwards. If this bubble be allowed to escape into the open air, it will rise very quickly, and soon be out of sight. Here we have a lighter air floating on a heavier air. Coal-gas, with which the bubble is filled, is much lighter than the air we breathe.

Experiment 63.—In this we propose to have an experiment which shall prove that the air has weight by a direct weighing, using the balance we referred to in Experiment 20, Lesson II. Get two of the lightest and best-shaped Florence flasks you can find, clean them well, and thoroughly dry them. Get a well-fitting soft cork for each. Bore through each cork a hole, to which fit a piece of glass tubing. Cut off a piece of tubing, long enough to go through the cork and extend about $\frac{3}{4}$ of an inch outside it. Over this slip a piece of india-rubber tubing about 2 inches long. Let it be of such a size as to fit the tube tightly. Moisten the tube before slipping the india-rubber over. When the india-rubber tube is turned down and tied tightly to the glass tube it should be air-tight.

Now put a loop round the end of the flask and balance it at one end of the beam; for this purpose you will remove one of the scale-pans. You will find small shot a good substance for a counterpoise. To make an experiment, balance the flask first with ordinary air, then put a small piece of glass tubing for a mouth-piece into the outer end of india-rubber, give a vigorous draw by putting this tube in the

mouth, nip the india-rubber tightly at the end of it, then give a second draw, relaxing the tube meanwhile, then turn the tube down, pinching it tightly, tie it in this position, weigh it again. If you have performed this operation successfully, the flask will now weigh less than before; the scale beam will no longer be horizontal, but pulled down on the weighted side. Now untie the tube: you will hear the air rush in, and the beam will become horizontal once more. This proves that you were able to draw some air out of the flask, then it weighed less; when the air got back again, it again balanced the weights.

Repeat the experiment by warming the flask, then closing it. Much more air can be driven out so, than by withdrawing it by the mouth.

Experiment 64.—Balance the two flasks; with a little shot you will soon be able to do this. Now open one of the flasks, and warm it, either by the flame of a spirit-lamp or a piece of lighted paper. The cold flask will soon out-weigh the other. Tie up the india-rubber tube, and let the flask cool down. Then open the flask, the air will rush in, and the flasks will again balance. Should the flasks not be air-tight, paint over the joints a thin layer of sealing-wax paint, a recipe for making which we give in the Appendix.

Two light flasks fitted with glass taps for this experiment can be obtained at a very small cost, but the exercise of making a piece of apparatus is a good one, and brings more satisfaction to the experimenter when it succeeds, than apparatus specially purchased for the purpose.

Experiment 65.—Balance the flasks once again.

Now remove one, open the tube and warm it considerably, pinch the tube so that no air can get back, then attach the mouth-piece to a tube connected with the coal-gas jet, let the gas be turned on so that the flask may be filled, tie it up and put it in its old place on the balance. It will weigh less than the other flask, proving once again that coal-gas is lighter than ordinary air. Remove the flask, take out the cork and fill with water, run this out, and put the flask away to dry, ready for another experiment. By no means be tempted to bring a light to the flask when it has the coal-gas in it.

Experiment 66.—This will show us that the air exerts pressure—*i. e.* it presses on everything it can get access to—because it has weight.

Take a wine-glass or a tumbler, fill it with water, cover the mouth of the glass with a piece of card, hold it tightly pressing against the glass, turn it upside down. Now remove the hand: the water will remain suspended in the glass, and the card at the bottom. This is due to the upward pressure of the air. Try the same experiment with a taller jar, the result is the same. Try it once again, using a thin piece of writing-paper instead of the card, to be sure that the card has nothing to do with holding up the water, but that the paper will do quite as well. The use of the paper is to separate the air from the water.

Experiment 67.—Take a glass tube, fit it with a plug by means of some darning cotton and a cork, attach a stiff wire to it, so that you can pull it backwards and forwards easily. It must be air-tight. Now, with the plug at the lower end, put the tube

into a saucer of water. Raise the plug slowly, the water will follow the plug, being pressed upwards by the air-pressure on the surface of the water, as in Fig. 27. Repeat this experiment with a glass squirt. This explains how it is that water is "lifted" in the common pump. The experiment may be repeated by withdrawing air by the mouth at the upper end of the tube.

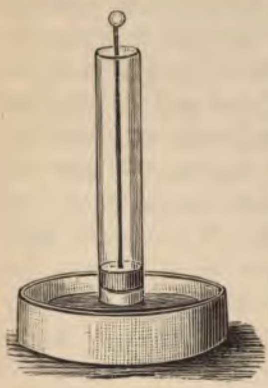

FIG. 27.

Experiment 68.—Take a circular piece of soft leather, smooth its under surface, put a small hole through the centre, through which draw a piece of twine, tie a knot on the under side—*i.e.* the rough side of the leather—flatten it, so that the hole is filled. Soak and soften the leather. Lay it flat upon a piece of wood or on a stone, flatten the leather well down, then try to lift it by the string. The stone will be lifted too, if you have been successful with your leather disc. This is sometimes called a sucker, but, as you see, its action is due to the air being shut out between the two surfaces. Bring two pieces of smooth glass together, put them flat on the table, lift the upper piece—the lower comes with it. Sometimes in plate-glass factories two sheets are stood face to face; they cannot be separated, and are therefore spoiled. The candles travellers fix in railway carriages to enable them to read in the badly-lighted compartments are fixed to the glass by a pad of india-rubber on this

"sucker principle." The term sucker does not seem a good one.

Experiment 69.—Take a wine-glass, light a piece of paper, hold the glass bowl over the lighted paper till it becomes warm, then plant it firmly into the fleshy palm of the hand. The glass will be held there, and the hand inside will swell into the glass. This is due to air-pressure. The hand may be turned about, but the glass remains fixed. The full reason you will be able to give after Experiments 63 and 64.

Experiment 70.—Take a tall jar—a pickle-jar will do—warm the air inside, as in the last experiment, dip the mouth into a saucer of water. The water will rise in the jar as the air inside cools, so that after a little time it will stand some considerable height above the water outside.

We learn the following from the experiments in this lesson—

1. That air can be weighed, if shut up in a close vessel.

2. 100 cubic inches of air weigh about 33 grs.; 1 cubic foot weighs $1\frac{1}{5}$ ozs. avoirdupois; 1 lb. of air occupies 13 cubic feet. Calculate the weight of air in any room of which you have the dimensions.

3. That warm air weighs less than cooler air.

4. Coal-gas and some other gases weigh less than air.

5. The air exerts pressure in consequence of its weight.

6. Water is lifted in an ordinary pump by air-pressure.

LESSON VIII.

EXPERIMENTS SHOWING AIR-PRESSURE.

BEFORE beginning our experiments we will ask you to cut a piece of black or blue paper that shall be 1 inch long and 1 inch wide, quite square, and mount it neatly in the centre of a sheet of note-paper as your standard square inch. Next cut in thin cardboard a figure that when folded up shall be 1 cubic inch—such a piece as we gave in Fig. 5, where each square is supposed to be 1 square inch; when cut, draw a penknife along the edges, so that they are partially cut through; they will then fold accurately, and, with a little gum or thin glue, can be held together, forming a cube of 1 inch. This is for a standard cubic inch. Now make a cubical box, so that the inside is exactly a cubic inch—leave one side uncovered. After making the edges secure, coat the outside with sealing-wax paint, so that even water will not run out. This is required to measure a cubic inch of material.

Air-pressure, about which our experiments taught us in our last lesson, is accurately measured by a barometer.

We want you to make a barometer, in its essential parts.

Experiment 71.—For this experiment you must have a glass tube about 33 inches long, $\frac{1}{8}$ inch to $\frac{1}{4}$ inch bore, closed at one end, 1 lb. of quicksilver, a small jar or tumbler, and a stand to which you can attach the tube to hold it in an upright position. Fill your barometer-tube with quicksilver. Perhaps you will say, "That is easier

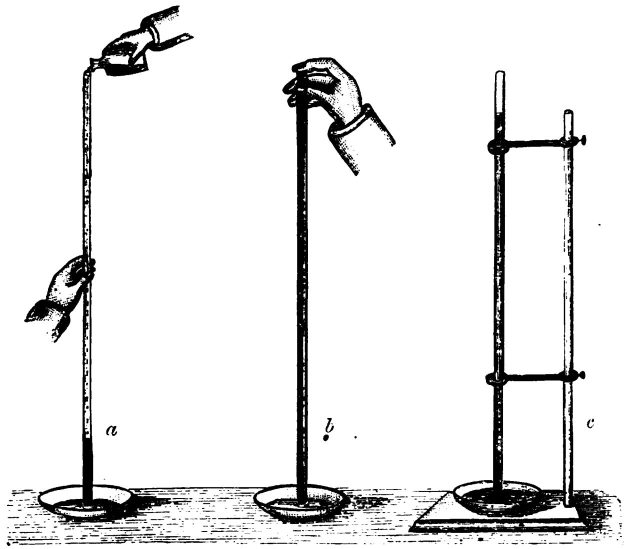

Fig. 28.

said than done," but with a steady hand and a little practice you will soon manage it. Hold the tube with the closed end in a basin, a cardboard box, or something that will catch the quicksilver that runs over. After pouring in about 10 inches, tap the tube, to give the air that has been carried into the tube with the quicksilver a chance of escape, then pour

in a little more; repeat the operation to get rid of the entangled air, and so on till the tube is quite full. Now pour a little quicksilver into the jar into which you are going to invert the tube. Close the end of the tube tightly with the forefinger of your right hand, press it very closely, then turn the tube

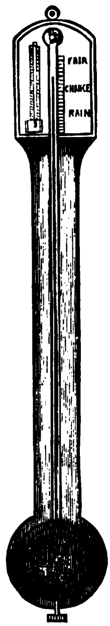

FIG. 29.

over so that the open end is well under the quicksilver, then remove the finger. A space of about 3 inches at the top of the tube will now be found empty. Fix the tube to the stand, taking care that nothing shifts the open end from the lower jar. Now get a tape-measure and see how many inches there are from the surface of the quicksilver in the jar to the top of that in the tube. If you have performed the experiment carefully this is generally about 30 inches. If you can have a standard barometer (Fig. 29) at hand for reference, all the better. See that the height of your column of quicksilver is nearly like that of your standard instrument. When we have performed this experiment before a class, our first question has generally been, "What is there in the top of the tube where the quicksilver has slipped down from?" We have had all kinds of answers, some of which most likely will be repeated to you if you put the same question to a number of young folks who have never seen the experiment before. This experiment is illustrated by Fig. 28, *a*, *b*, *c*.

The experiment, as we have given it here, was per-

formed by Torricelli, the celebrated pupil of Galileo, in the year 1643, and this led to the invention of the Barometer. The empty space above is called the Torricellian vacuum. As you cannot perform experiments with a barometer very well without an air-pump, we shall only introduce one.

Experiment 72.—Get a pickle-jar, with a mouth wide enough to allow the jar in which the barometer stands to be lowered into it, then fit a large bung to it, bore a hole for the barometer tube, and another through which a piece of glass tube is to be pushed, so as to fit it tightly. You cannot fit them quite air-tight, but with soft cork and a thin band of india-rubber round it, much can be done towards securing this. Make a little wire cage, with two or three long strands of fine iron wire: with this you can lower and raise the barometer into and from the jar.

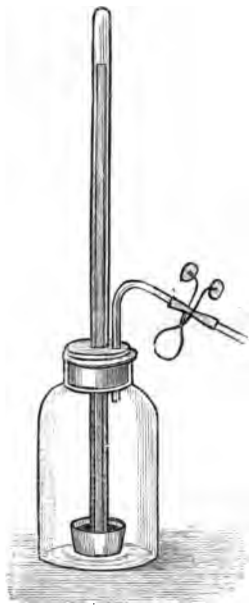

FIG. 30.

When placed in the jar the arrangements are as shown in Fig. 30. Now place over the open tube a piece of india-rubber tubing, having a mouthpiece at the other end; then withdraw, by means of the mouth, some of the air—give a vigorous draw, then pinch the tube so that the air does not return. Watch

its effect on the height of the quicksilver: it will fall. Give, as quickly as you can, another draw: the column will fall still lower. This proves beyond a doubt that the height of the quicksilver column depends on the pressure of the air. At first it is the same as if open to the outside air, but when you shut it up with the cork and tube, and draw some of the air out of the bottle, there is not so much air to sustain the column, it must therefore fall. Let the air in again gradually, and watch the quicksilver go back to its old place.

Experiment 73.—Reverse operations, and blow gently but firmly into the bottle: the quicksilver will rise in the tube. Keep the extra air there by tightly pinching the tube. The variation of height should be registered by moistening little bits of postage-stamp paper and sticking them on the tube.

Experiment 74.—Fix up your scales, and balance the cubical box, having an inside capacity of 1 cubic inch. Fill the box level full of quicksilver, put a half-pound weight into the other scale-pan, and it will balance the quicksilver. One cubic inch of quicksilver weighs half-a-pound avoirdupois, therefore 30 cubic inches weigh 15 lbs.

Experiment 75.—Get a bent tube, about $\frac{3}{8}$ inch diameter, with a short leg about 3 inches long, and the longer leg about 15 inches. Tie the long end of the tube to the stand used as the support for the barometer, or slip two strong elastic bands over tube and stand, this will answer the same purpose, as shown in Fig 31. Pour into the short end sufficient quicksilver to fill the curve, and about half-an-inch above on

each side. Now pour water into the long arm of the tube, till the quicksilver stands 1 inch above its former position, paste a slip of paper at each of these heights shown by the quicksilver before and after the water was poured in. Measure the height of the water: it will be found to stand $13\frac{1}{2}$ inches high, and the quicksilver 1 inch high. This shows that 1 inch of quicksilver balances $13\frac{1}{2}$ cubic inches of water, and must weigh therefore half-a-pound. In other words, quicksilver is $13\frac{1}{2}$ times as heavy as water. Multiply 30 by $13\frac{1}{2}$ and you get 405 inches, or the height of water barometer when the quicksilver barometer is at 30 inches.

FIG. 31.

Experiment 76.—Take a pile of about twenty books, bricks, or wood blocks, place them one above another. Which book bears the greatest weight? What would happen if the books were very elastic? Compare these to layers of air, and how it explains that the lower layers of air being pressed by those immediately above them must as a consequence be denser, so that a cubic foot of air at the surface must be heavier than a cubic foot above the earth's surface. Think out and explain how it is that the quicksilver column falls when the barometer is carried higher and higher above the sea-level.

Experiment 77.—Take a glass tube 18 or 20 inches long, and of $\frac{1}{4}$ inch to $\frac{3}{8}$ inch bore, fill it with water, close the upper end firmly by the pressure of the forefinger. Raise the tube, keeping the finger well down,

the water is lifted too; raise the finger, the water at once runs out.

Experiment 78.—Take the bent tube used in Experiment 75. Stretch over the end of the long arm a piece of bladder or of sheet india-rubber, tie it securely, so that it is air-tight. Now fill the long arm with water, turn it over: the column of water is sustained. Why?

Prick a hole through the covering: the tube is soon empty.

Experiment 79.—Take a small phial—an ounce phial will do—nearly fill it with water, leaving a bubble of air at the closed end; adjust this quantity so that it just floats in water. Now take a wide-mouthed jar, nearly fill it with water, float the phial in this. Stretch and tie over the mouth of the jar a sheet of india-rubber. Press upon the india-rubber, the phial sinks; raise the hand, and up comes the phial and floats again. Repeat the experiment. Why does the phial alternately sink and rise?

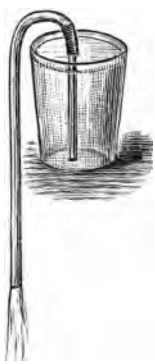

FIG. 32.

Experiment 80.—Take the bent tube used in Experiment 75; by means of a short piece of india-rubber tubing add about three inches more of glass tubing to the shorter end. Now fill it with water, close both ends with the middle finger of each hand. Turn it over, putting the shorter end into a jar of water, remove the fingers: the vessel will quickly be emptied of its contents. The arrangement is shown in Fig. 32, and is called a syphon. Why is the vessel emptied?

Why is the shorter and not the longer end put into the vessel?

From these experiments we learn—

1. That air-pressure will support a column of 30 inches of quicksilver, or a column of water 13½ times as high, or 33 feet 9 inches.

2. That this pressure is equal to 30 half-pounds, or 15 lbs. per square inch.

3. That a vacuum exists between the top of the barometer-tube and the top of the quicksilver. This is called the Torricellian vacuum (Expt. 71).

4. That the smallest differences of air-pressure are noted by the barometer.

That a barometer can therefore be used for measuring heights.

A barometer standing at 30 inches at the earth's surface would only stand at 29 inches if raised 1000 feet above the surface, at 28 inches at 2000 feet above, and so on for the first 3000 or 4000 feet.

LESSON IX.

THE COMPOSITION OF THE AIR.

WE have learnt a good deal about the air and its general properties of weight and pressure. We will now change our line of experiments, so as to learn something about what it is made of, and how the substances in it help a candle to burn, and animals and plants to live in it.

The experiments with air that we have already done are said to be physical; those which aim at finding out what the air or any other substance is made of are said to be chemical. Our next inquiry, then, is into the chemical properties of the air.

Experiment 81.—In an earlier experiment we found that a candle would only burn for a very short time when covered over closely with a glass or any other vessel. Take such a jar once again—a pickle-jar will do. You require besides, a slip of cork, a piece of phosphorus, a dish of water. Cut a small piece of phosphorus about the size of a small pea, dry it on blotting-paper, place it on a slip of cork which is floating on the water in the dish. Set fire to the phosphorus, cover it over with the inverted jar, press it down level, and keep its mouth under water, so that no fresh air can get in. The arrange-

ments are shown in Fig. 33, where P is the phosphorus.

N.B.—In using phosphorus be very careful. It has to be kept under water, it is very imflammable,

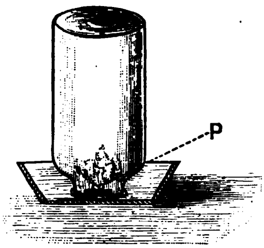

FIG. 33.

and if rubbed hard will take fire. Its burn is bad, therefore do not touch it with a heated hand. When you have cut off the piece required, put the rest back at once into the bottle, fill it up with water. Dry the phosphorus by pressing very lightly with blotting-paper, or a dry cloth. If not dry it flies about when set light to, and will perhaps break your bottle.

While the experiment is going on, watch the bottle; it gradually fills with a dense white smoke, and the water rises from the saucer to a little more than one-fifth part of the height. The phosphorus will cease to burn after a short time, then you must wait till the smoke clears away, *i.e.* settles down, and leaves the glass clear above the water. Next you have to examine the contents of the jar, to see that there is no change. To do that you must let no water out, and no air in. Slip a piece of slate or glass plate under the mouth of the jar, hold it there while you turn it over. Keep the cover on. Can you see the

air above the water, any more than you could see it before you tried the experiment? Now light a match and gently slide off the cover, put in the light: it is at once extinguished. Try it again, the result is the same. Do not keep the cover off any longer than you can help. Call attention to the fact that you have now something in the bottle that will not allow a candle or anything else to burn in it, yet is as colourless as the air, and being not changed in appearance, there is nothing but the extinguishing of the light to tell you that it is not air. Did you notice the progress of the experiment from first to last? When the phosphorus was first lighted, it warmed the air so much that some was driven out. Also that when the whole got clear, the water filled a little more than one-fifth of the jar.

Experiment 82.—Take a Florence flask, fit it with a very good soft cork. It must be air-tight. Remove the cork; put into the flask a similar piece of dry phosphorus to that used in the last experiment. Cork it up tightly. Heat the phosphorus by holding the flask over a spirit-lamp, moving the flask round all the time. The phosphorus will roll about the flask and soon fill it with a similar dense white vapour to that we had in the last experiment. Keep this on till no more smoke is given off. Let the flask cool, then open its mouth under water: some water will rush in. Do not be tempted to lift out the flask till all the smoke has cleared away. You can help this by shaking the water about, but not so as to lift the flask out of water. When quite clear, put a piece of postage-stamp paper on to mark the height, then cork up the flask again. You must now get the air that

is in the flask into a wide-mouthed bottle. To do this fill a bottle with water, invert it in a deep dish or bucket. Now dip the neck of the flask into the same vessel of water, uncork it, and bring the neck under the mouth of the jar. Bring the flask on to its side, and the air will bubble from the flask into the jar. With a lighted taper or match test this air, see if it acts the same as that in the last experiment. If it does, we shall be inclined to think that both this and that in the last experiment are alike.

Now measure the quantity of water that was in the flask by filling it up to the mark previously made. See how many such measures of water are required to fill the flask—it will be five, if you have performed the experiment carefully.

Experiment 83.—Take a tube closed at one end—a 6 inch × ½ inch test-tube will do—attach a piece of phosphorus to the end of a wire, put it into the tube within an inch of the top, fill the tube three-quarters full of water. Then close the mouth, by tightly pressing the middle finger to it, and dip this end of the tube under water contained in a tumbler or jar, leaving the phosphorus suspended in the portion of air above the water. Mark the level of the water in the tube by a piece of postage-stamp paper outside the tube, set it aside for twenty-four hours. The arrangement is shown in Fig. 34. Then note the rise of water in the tube, compare it with that still containing air, test the remaining gas with a lighted

FIG. 34.

match, which will be extinguished as in the other two experiments. The proportion of air left after using the phosphorus has been the same in each case. In no case has the phosphorus all been used up, so that it was not because there was no more phosphorus that the substance ceased to burn, but evidently because it had taken up in each case all the substance there was which allowed it to burn.

Experiment 84.—Take another test-tube similar to that used in the last experiment, fit a good soft cork to

Fig. 35.

it, bore a hole through the cork to fit a tube bent like the letter L,—you know how to bend this, as we directed in Experiment 43,—cut a second piece of tubing about 3 inches long, of the same size as before, take about 10 or 12 inches of india-rubber tubing to join these together, and you will have an arrangement as shown in Fig. 35. Get from the druggist 1 oz. of powdered chlorate of potassium, and about the same quantity of oxide of manganese,—1 lb. of the latter only costs a few pence. Take a small quantity of the

former, about as much as will heap on a sixpence, put it on a piece of paper, add nearly the same quantity of the oxide of manganese, and mix them thoroughly together. Put the mixture into the test-tube, put in the cork with tube attached, fasten it to a stand with a clip or a piece of twisted iron wire ready for use.

Now perform Experiment 81 again. Let the jar stand till you have a clear column of gas over the layer of water, which in each case has come to about one-fifth part of the whole. Fix the tube containing the potash mixture conveniently for heating. It must be heated gradually by moving the flame of the lamp up and down it for some time, then concentrate the heat on the lower part, where the mixture is. Drop the end of the tube into the vessel of water in which the bottle with the result of the last experiment stands, and when bubbles come off very freely, put the tip of the tube under the mouth of the jar: the jar will soon be quite full. Then withdraw the tube and allow the mixture you have been using to cool gradually. Now cover the mouth of the jar, remove it, and examine its contents by the taper test. You will find that the taper burns as in ordinary air. The gas driven off from your potash mixture must have replaced that taken out by the burning phosphorus. The gas driven off from the potash mixture chemists call oxygen.

This experiment proves that air consists of four-fifths of one kind of gas that will not allow substances to burn in it, or animals to live in it, and one-fifth of a gas that when added to the four-fifths reverses these qualities.

Experiment 85.—To see how this oxygen gas

acts by itself. To do this, some of the gas must be prepared, and an interesting experiment it is to prepare some. Suppose we wish to have four bottles of this gas. First get the bottles. If you have no proper gas-jars, get four pickle-bottles—they are convenient because they have wide mouths and smooth rims. The test-tube fitted will do again, if sound, but sometimes if chilled suddenly it breaks up. Fit up therefore a Florence flask, and it will last you some time if you are careful in heating and cooling it. After use, to get out the remains of the potash mixture, do not try to poke it out or stir it with a stick, but pour some water in and let it stand: the stuff loosens and pours out. It may be stood aside to dry, and pounded up and used again, for it is the manganese, which is not altered and may be used over and over again, adding fresh potash each time. Having made these preparations, fill the bottles with water, cover the mouth of each, invert it and stand it in a basin or dish, and so on till all are ready. Then gradually heat the flask containing four or five times the amount of potash mixture mentioned in the last experiment. When the bubbles have come off freely for a few seconds, put the end of the tube under the mouth of one of the jars, the water will soon be displaced by the gas. As one bottle fills, go on to the next, and so on till all are filled. Remove the tube, stand aside the flask to cool. Do not put it in a draughty place nor touch it with water; let it cool gradually, and it may be cleaned out and used again and again. You have now four bottles of clear, colourless, invisible gas. Cover the mouth of each bottle closely with a piece of slate or a glass plate, or

even a piece of paper, over which put a small slab of wood. The arrangements for collecting the gas are shown in Fig. 36.

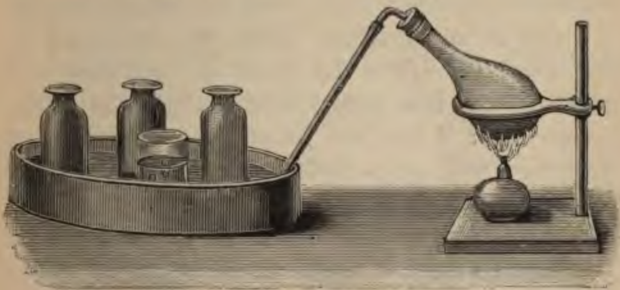

FIG. 36.

Experiment 86.—Cut some slips of wood as thick as match-stalks, but four times as long; take one of the bottles of gas, light a slip of wood. When burning brightly blow out the flame, leaving a spark at the tip, slide aside the cover, plunge the spark in: the wood re-lights and burns furiously. Withdraw it, slip on the cover, blow out the flame, repeat the experiment. This you can do as long as successful. When the re-lighting takes place no longer, cover up the jar and set it aside.

Experiment 87.—Take a piece of charcoal—charcoal bark if you can get it—twist round it a piece of wire, heat the corner of it in a lamp-flame till it is red-hot, then slip aside the cover of a second bottle, plunge in the charcoal, cover up the jar. With what brilliancy the charcoal now burns, yet how sluggishly before! When the flame dies out remove the charcoal, slip on the cover, and stand the jar aside.

Experiment 88.—Coil 2 or 3 feet of thin iron wire round a pencil, slip it off, stretch it out to about 4 inches. Attach to one end of the spiral a match in such a manner that when lighted the end of the wire is in the flame. Draw the other end of the spiral through a flat piece of wood that will cover the jar. Now take a third jar, light the match, plunge the coil into the jar of gas. The spiral of iron wire will burn brilliantly, the melted iron dropping on the bottom of the jar, into which it will bury itself by melting the glass, unless a small quantity of water has previously been put in. This is a good precaution to take, as the water saves the bottle from being spoiled.

Experiment 89.—Make a small tin cup, by hammering a flat disc of the metal about the size of a farthing on to the rounded end of something hard enough to endure it. Attach to it some strands of wire, by which you can suspend it. Bring in readiness the fourth bottle of gas, put into the metal cup a small piece of sulphur, hold it in the lamp-flame till it first melts, then burns; now gently lower it into the bottle of gas. It burns with a bright, violet light. Do not hold your mouth over the jar, for the fumes are very irritating to the throat.

Experiment 90.—Take the bottles used in Experiments 86 and 87. Pour into each a little lime-water, which will be turned milky as in some former experiments, showing that probably it is due to the same cause, or the presence of the same substance. Into the jar used in Experiment 89 put a blue solution, made from steeping a red cabbage leaf in half-a pint of water, or from litmus, the latter the druggis

supplies; sixpence will buy a quarter of a pound, which will last for a considerable time for making solutions. Both these solutions are delicate tests for the presence of acids. From the experiments in this lesson we learn—

1. That air consists of a mixture of two invisible gases, in the proportion of four parts of one to one part of the other.

2. That when a body burns, it combines with or takes to itself that gas which is present in the smaller quantity.

3. The gas present in the larger quantity extinguishes flame, and will not therefore support life. The active gas is that present in the smaller quantity, and supports flame vigorously and carries on life actively. The inactive gas is called nitrogen, the active gas is called oxygen.

4. That oxygen can be obtained by heating certain substances containing it, especially chlorate of potash.

5. That whatever substances burn in air, burn much more vigorously in oxygen, and in burning produce a new substance.

LESSON X.

BREATHED AIR AND FRESH AIR CONTRASTED.

WHEN doing these experiments for our own instruction or for the benefit of a class, we must remember that our special object is to learn what the experiment is to teach, so that although doing the experiment is very interesting, and requires some care and patience, yet under all this there is something to learn besides, and not only should we observe closely for all changes that take place while we are performing the experiments, but learn why they take place, and why we are told to do this or that in the various steps of our experimental inquiries.

Experiment 91.—To see if there is any difference between fresh and breathed air. Take two of the jars such as you have been using for collecting oxygen. One is to be filled with breathed air. To do this, fill the jar with water, invert it in a basin of water, as for collecting gases. Take a piece of tubing through which you can blow — the tube attached to the oxygen flask will do—put one end under the edge of the jar and the other into your mouth (Fig. 37), then blow air from the lungs into the jar : the water will soon be replaced with breathed

air. Test it with the lighted taper and with lime-water. Compare these results with those obtained from a bottle of ordinary air, for we see that breathed air neither supports burning nor allows the lime-water to remain clear.

Repeat this experiment, getting some member of the class to breathe a bottle of air. The specimen of fresh air should be collected from the open air, and not in a room where several persons have been breathing. To do this fill the jar with water, carry it outside, then tilt it up, and as the water runs out

FIG. 37.

fresh air rushes in. This is the specimen to be contrasted with the breathed air.

Experiment 92.—Compare the air in the upper part of the room, *i. e.* towards the ceiling, with that in the lower part of the room. Take two bottles of the same size—pint bottles are suitable—collect air from the parts you wish to contrast, in the manner pointed out in the last experiment; put into each bottle half-an-ounce of lime-water: that of course which gives the least cloudiness to the lime-water is the purest. In a well-ventilated room there should be no cloudiness produced in the lime-water by the air collected in the lower part of the room. As heated air and breathed air rise, and collect in the upper part

of the room, there is likely to be such a cloudiness produced in a sample so collected.

Experiment 93.—Stand a saucer of clear lime-water on a table or shelf, where it is exposed to the air. After some time it will be covered with a chalky film; pour this into a glass and shake it up, it will be milky and thick. Is this milkiness caused from oxygen or nitrogen, or from neither?

Experiment 94.—We will now make some few experiments with the gas that makes lime-water milky. It is sometimes called chalk-gas, because it can be obtained from chalk. We have called it carbonic acid gas. The reason for this we shall see better later on.

Take a piece of chalk—not prepared chalk such as you write on the board with—but a piece of ordinary chalk, such as you see in a chalk-pit, and in some railway cuttings. A piece about the size of an ordinary egg can be taken. Let it get dry, then weigh it, put down in grains what it weighs. Put it into a clear fire, let it get red-hot, and remain so for some time. Remove it from the fire, allow it to cool, keeping it in a dry place meanwhile. Then weigh it again; compare it with the former weight. If carefully performed it should lose 44 out of 100 grains by this heating, so that what is left per 100 grs. = 56 grs. It was chalk when it went into the fire, it is lime now it comes out of the fire.

If a piece of marble be treated in the same manner you have the same result. Marble is crystallized chalk. Lime, but not chalk, is used in making mortar for building purposes.

Experiment 95.—Take two tumbler glasses, pu

into one a piece of chalk, into the other a piece of lime, put a little water on each piece. We have already, in Experiment 33, told you what will happen in the case of lime; with the chalk nothing happens. Add a little strong vinegar to each. The chalk now seems to be giving off bubbles of gas very freely, but not so the lime. Test the gas that comes from the lime with lime-water. This was the gas that was driven out of chalk when burnt in the kiln.

FIG. 38.

Experiment 96.—To prepare this chalk-gas, fit a bottle with a sound cork and leading tube, as in Fig. 38. Put into the bottle some pieces of marble or chalk, cover them with a little water, then add strong vinegar, or, still better, hydrochloric acid, which is very cheap. Carry the leading tube from the bottle into a dry bottle, which you require to fill with the gas; keep the mouth partially covered with a slip of paper. You can tell when it is full by a burning match. The gas is clear, and as colour-

less as the oxygen and nitrogen you have been using.

Experiment 97.—Light a small piece of candle, lower it into a tumbler, pour into the tumbler some gas from the bottle collected in the last experiment: the candle is at once extinguished. Take out the candle, upset the tumbler, and the gas will be poured out. The taper may be re-lighted and the experiment repeated.

Experiment 98.—Take a large-sized paper bag, fold it so that it will keep open, and you can suspend it by threads to one end of your scale-beam; balance it; pour into it a supply of chalk-gas, prepared as in Experiment 96. It will pull the beam out of the horizontal, showing that it is heavier than air.

Experiment 99.—Collect another jar of this gas, pour into it a little water, cover it down closely, and shake it up. The cover will be held forcibly down by air-pressure, for some of the gas has been absorbed by the water. Now pour in a little litmus solution: it will be reddened. This proves that the gas is acid.

Experiment 100.—Collect some of this gas in a basin, cover it over while you blow a soap-bubble. Drop the soap-bubble into it: it will float on the gas, instead of falling to the bottom of the bowl.

From this lesson we learn that—

1. Fresh air does not alter the appearance of lime-water, but breathed air does; the latter must therefore contain carbonic acid gas.

2. That air containing only oxygen and nitrogen does not change the lime-water, but Experiment 93

proves that there must be a small quantity of carbonic acid gas even in ordinary air.

3. That the larger portion of the carbonic acid gas is thrown into the air by the breathing of animals, and the burning of substances.

4. That chalk contains lime and carbonic acid gas; that this gas is turned out of the chalk either by heating, as in a lime-kiln, or by the action of a strong acid like vinegar or hydrochloric acid.

5. That carbonic acid or chalk-gas is heavier than air; this can be shown by rough weighing, as in Experiment 98.

LESSON XI.

HOW GASES DIFFUSE IN AIR.

EXPERIMENT 101.—Fill a tumbler glass or bottle with the chalk-gas prepared as in Experiment 96. Heat a piece of iron attached to a wire, or use a small poker—heat either till it is red-hot. Then uncover the prepared jar, and, without touching the bottle, lower the heated iron into the jar. Let it remain there for a short time, then remove it. Test the air in the jar: it will be found that the heavy chalk-gas or carbonic acid gas is gone. The heat has made it lighter, and helped it to make haste to distribute itself among other air.

Experiment 102.—Collect a second jar of chalk-gas, stand it on the table, place over its mouth an inverted jar of fresh air, leave them for a short time. When you remove the upper jar, test it with lime-water. You will find some of the gas from the lower bottle has got into the upper, for the lime-water will now be turned milky. Heavy gases in the air distribute themselves without being heated as in the last experiment, but they do so more quickly if they are heated.

Experiment 103.—Take a lamp-chimney with a wide body and narrow neck, as in Fig. 39. Light a

short bit of candle, stand it on the table, and put the chimney over it: the flame is soon extinguished. Now cut a piece of thin sheet zinc, as in *a*, Fig. 39,

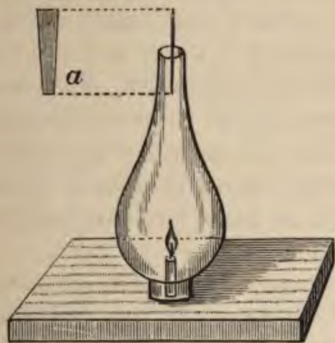

FIG. 39.

so that it will go into the neck of the chimney about 3 inches, dividing the shaft into two parts. Now light the candle, and after a very short time you will find air going down on one side and coming out at the other, and the candle will burn as freely as it does in the open, and the flame will be much more steady. You can test the direction of the outer or inner air by holding a smoking match-stalk: the smoke will be carried outwards or inwards according to the direction in which the air is travelling.

We have seen that animals breathing and substances burning produce carbonic acid gas, which spoils the air for breathing again, and it is the business of good ventilation to carry this air away.

Experiment 104.—Take a sprig, freshly plucked, of laurel, rosemary, or of any plant with fleshy leaves, put it into a tumbler of water inverted in a plate

of water, and stand them in the sunshine. You will soon see the inside of the glass covered with bubbles. These will collect at the top of the glass, and more readily when the glass is gently tapped frequently. After a time, collect this gas in a test-tube, by decanting it under water, as we mentioned in the case of Experiment 82. Examine this gas, it will turn out to be oxygen. Plants absorb the carbonic acid, and then by a process of getting material which is natural to it, it separates the carbon, which it keeps for itself, and sends oxygen back into the air.

The air is a *mixture* and not a compound of oxygen and nitrogen. In this mixture the oxygen keeps its own properties and qualities, and the nitrogen does the same.

Experiment 105.—Take a quarter of a pint of grey peas and a pint of white peas, mix them and shake them up together; but shake them up together as much as you like the peas still remain distinct. The particles of oxygen and nitrogen are so infinitely small, that you cannot inhale them except as a mixture; but the gases remain as distinct as the peas.

Experiment 106.—Collect a quantity of carbonic acid gas in a bowl, stand it on a table covered loosely with some blotting-paper, leave it standing for half or three-quarters of an hour, then examine the bowl. You will find the heavy gas gone, and the air in the basin much the same as the ordinary air. Air and gases mix, or diffuse, even through plaster, brick, and stone. In an ordinary fresh air the quantity of carbonic acid is only 1 gallon in 2500 gallons of air.

Experiment 107.—Take a tumbler glass of freshly-drawn cold water, wipe the outside of the glass quite dry, carry it into a warm room. The outside soon becomes covered with moisture. Where does this moisture come from? Not from the inside of the glass.

Experiment 108.—Obtain from the druggist a small quantity of chloride of calcium, put a portion of it in a saucer on the table, and allow it to stand for a short time, then examine it: it will be very moist, especially if many persons are in the room where the experiment is performed.

Experiment 109.—Repeat the above experiment, by weighing out a portion of the chloride of calcium. Call attention to the substance being exactly balanced by weights in the opposite scale. Leave it for a short time, it will be quite clear that the scale containing the salt is getting heavier, for it will soon hang much lower than the other.

Experiment 110.—Secure a branch of sea-wrack or tangle, when you go down to the sea-side for your holidays. Hang it up in a room or in a passage where the outside air gets to it. Notice day by day the condition of it; sometimes it will be limp and soft, sometimes crisp and dry, and at others not very dry or very wet.

Where does the moisture come from to affect the substances in the last three experiments? From Experiment 110 it is evident also that the moisture is a variable quantity. This moisture is in the air, mingled with the various gases our experiments have told us about.

From this lesson we learn that—

1. The air consists mainly of two gases, oxygen and nitrogen. There is present also a small quantity of carbonic acid and water-vapour. The first three are tolerably constant, the water-vapour is very variable in its quantity.

The average composition of the air is generally given as follows. In 100 parts by volume:—

Oxygen	20·61 parts
Nitrogen	77·95 „
Water-vapour	1·40 „
Carbonic acid	0·04 „

Traces of other substances are present in very small quantities in different localities.

2. That the gases in the air do not arrange themselves according to their weight, but intermingle irrespective of weight. This diffusion takes place through porous walls and partitions.

3. That ventilation is assisted by differences of temperature in different portions of gas in a room or round about the room.

4. That breathing animals and burning substances throw carbonic acid into the air.

5. That healthy living plants in sunshine decompose carbonic acid and give oxygen back to the air.

6. That air contains moisture. This is given off into the air by the breathing of animals, burning of substances like candles, gas, oil, wood, and other inflammable substances, and by a process called evaporation, about which we shall learn something later on.

LESSON XII.

DIFFERENCE BETWEEN A LIQUID AND A SOLID.

In our early experiments we saw that water is produced when a candle is burning in the air. The water in the air generally exists in the form of vapour, and is invisible, but if the air is cooled it shows itself as mist or fog, and if this is brought on to a colder surface still, the small drops collect into larger drops, and trickle down the sides of the cold object.

Nothing is more familiar than the water trickling down the inside of the windows of a sitting-room when the air outside is cold.

Experiment 111.—Hold a dry tumbler over a candle-flame, the moisture collects on the inside, the tiny drops run together, till at last large drops run down the inside. Here we have drops of water formed from something that is burning in the candle combining with the oxygen of the air.

In its ordinary condition water is a liquid. In this condition we shall ask you to try some experiments with it as we did in the case of air, then we shall see what the substance is that forms water when burning goes on in air, and study the properties of this substance by itself. Water is such a common substance, we are so familiar with it, and we at first sight think

we know a good deal about it; but when we look at it systematically, and do our experiments thoughtfully, we shall learn a good deal that we had not thought of before, and see how interesting a subject it is.

Experiment 112.—Dip the fingers into water: on lifting them out you notice large drops hanging to them. Dip in a dry flask—bulb part downwards—a still larger drop hangs to it. To make these large drops a great many small drops must hang together, and even the smallest drop that can be seen is made of still smaller, as seen in the last experiment.

Experiment 113.—Take a lump of chalk or sandstone, some very fine dry sand, a glass of water, and a glass of treacle: notice the difference between a solid and a liquid. Pour out the sand and the water on to separate plates: notice that the water spreads out, and it does so quickly; the sand remains in a heap, and will only spread itself out when shaken; the particles of water move freely and smoothly over each other, those of the sand do not. Here is one of the differences between a solid and a liquid. Now pour both these substances back into glass vessels: the water takes the shape of the inside of the vessel at once, the sand only does so when shaken or jerked. The solid lump keeps its shape in a tumbler or on a plate wherever it may be placed, and if its shape has to be altered force must be used. Pour out the treacle, it will act similarly to water, but its movements are much slower—this and such substances are, as it were, half-way between solids and liquids.

The attractive force called cohesion exists more largely in the solid than in the liquid.

Experiment 114.—Bend a piece of soft iron wire

into a hexagon—six-sided shape—carrying a strand towards the centre, then turn up the piece in the centre. Place the frame on a table, to see that it lies quite flat; if inclined to turn up at any corner it must be hammered so as to keep quite flat. Now place it flat upon a glass of water, as in Fig. 40: it will float; the cohesion in the skin of the water will prevent it from sinking. Float a needle on the surface of water. It must be carefully placed on the water, quite flat, so that the point or head does not dip in the least.

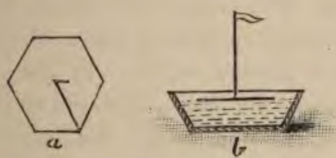

FIG. 40.

Experiment 115.—Pour water into vessels of different shapes. Notice that it runs immediately into every crevice, and that if stood side by side, the surface of one is quite parallel to that of another. From this explain why "liquids maintain their level."

Experiment 116.—Take a glass, fill it quite full of water, drop into it some finely-powdered salt; drop in little by little for some time, as long as you can without the liquid running over. When the glass is already full, how is it you can put in salt?

Experiment 117.—Mix together some salt and fine sand, stir the mixture into a glass of water: it will be muddy. Now put a filter-paper on to a funnel and run the mixture through it into a clean glass. If

carefully done, the mixture will come through quite clear. Look for the sand and salt on the paper. The sand will be found, but where is the salt? Taste the clear liquid, you now have your answer. The salt was dissolved in the water, the sand was only mixed, so the filter-paper could separate the latter from the water, but not the former. In the clear liquid we have a solution of salt—water is the solvent.

This experiment will be the more striking if the sand, salt, and water are weighed separately, and weighings be made at each stage of the experiment.

Experiment 118.—Take two small tumblers of water, weigh them, suspend a piece of sugar in one tumbler, and a piece of sulphur in the other. The sugar disappears in a short time, not so the sulphur. Take out the sulphur, weigh the tumblers again; that in which the sugar dissolved now weighs more.

Experiment 119.—Pour the water containing the sugar into a saucer, stand it on the hob near the fire. The water will soon disappear, and you will again see the sugar, which is left behind. If you weigh the sugar before putting it into the water, and weigh it now, you can tell whether or not all is left behind, or if any has by any chance been lost.

Experiment 120.—Put some water into a small shallow saucer, weigh it. In the morning stand it out in the open air, but so protected that it is in no way interfered with; in the evening weigh it again. If any is left, stand it out again the next day; repeat the weighing until none is left. Where has the water gone to? How did it go?

We learn from this lesson—

1. The difference between a liquid and a solid.

2. That in a solid the particles hang together strongly, but in a liquid they are easily separated.

3. That substances heavier than water will under some conditions float on water.

4. That dissolved solids exist in the solvent in very small particles, too small to be seen.

5. That a substance dissolved in a liquid may sometimes be recovered in full if the liquid is driven off by evaporation.

LESSON XIII.

WATER AND SUBSTANCES IN SOLUTION.

WHEN a substance is in solution, the weight of that solution is the sum of the weights of the solvent and the substance dissolved.

When water or any liquid has dissolved as much of a substance as is possible, the solution is said to be a "saturated solution."

Experiment 121.—Take a quantity of water in a flask, dissolve as much saltpetre or Epsom salts as you can while it is cold. This you can test by adding still more of the substance, which will settle down at the bottom of the flask when the solution is saturated. Now heat the flask, and more of the substance will be dissolved. In this case hot water dissolves more of the substance than cold water does. Allow the substance to cool. A portion of the salt will settle down again at the bottom of the flask, the solution above remaining clear.

Experiment 122.—Take samples of drinking-water, sea-water, sugar and water, lime-water, stand them in the open air on a dry day, in the sunshine if possible: after a time the water will be gone. Examine what is left behind in each case. Learn how

it is that natural waters take up substances in solution.

Experiment 123.—Take two half-pint tumblers, partially fill them with water—say three-quarters full—put into one a quantity of salt, let it dissolve, add enough to make a tolerably strong solution. Take an egg, carefully place it in the solution of salt and water—it floats. Now remove it to the clear water—it sinks. Why should the egg float in one case and not in another? Why does a heavily-laden vessel, almost water-logged in the river, float so much better when it reaches the sea?

Experiment 124.—Balance two small tumblers, put into them equal quantities of water, weigh out equal portions of salt; in one case put the salt in the water, in the other case put the salt outside in the scale-pan, both should still balance.

Experiment 125.—Take a piece of heavy wood, oak or ebony, also two tumblers of water; into one of these put some salt, stir it up so that it becomes a clear solution. Drop the wood into the water and, with a pencil, mark the point to which it sinks. Now remove it to the solution of salt and water, it will float much higher; mark also the point to which it sinks. Now take a third tumbler, add some methylated spirit to the water. The wood will sink much further than it did in the water, perhaps it will sink altogether, it depends on the wood you are using, and in the quantity of spirit added to the water. Strips of wood, kept vertical by suitable guides, are best for these experiments.

Experiment 126.—Take the two small tumblers used in Experiment 124. After balancing them as

before, put a quantity of water into one tumbler, and an equal volume of the mixture of spirit and water used in the last experiment. The lightness of the mixture compared with water will soon be apparent, and will explain why the wood sinks so much further in it than in the water only.

The lifting power of liquids, known by the word "buoyancy," is easily explained by these experiments, and will be found to increase as the weight of the liquid increases.

Experiment 127.—Pour the quicksilver used in the barometer experiment into a dish, put on it all sorts of heavy substances like stone, iron, glass, chalk: notice that they all float. Do not put gold on to it. Gold would sink, but it would also have its surface interfered with, spoilt perhaps before you could recover it.

It is now a good opportunity to compare the weights of common and familiar liquids with each other, such as oil, milk, tea, coffee, beer, and various solutions; this can either be done by the two-tumbler arrangement as mentioned in Experiment 126, or by means of the U-tube, which we have before recommended for balancing water and quicksilver.

Experiment 128.—In this experiment we want you to float a lighter on the top of a heavier liquid. Make a strong solution of salt and water, get it quite clear; put it into a large tumbler, enough to make it half full. Now by means of a funnel with a fine stem pour on to the top some clear tap or rain-water. Hold the neck of the funnel close to the inside of the tumbler, so that it does not break up the surface of the salt-water. On holding the glass up to the

light and examining it closely, you can see how far the salt-water extends up the glass, but persons at a distance cannot distinguish. Now drop an egg gently into the glass, it will fall till it comes to the layer of salt-water; here it stops. It seems almost like magic that the egg remains suspended in the midst of the liquid, to any one not acquainted with the secret of the solution. If allowed to stand for some time, the distinction between the layers of salt and fresh-water becomes less and less distinct, till at last the water becomes uniformly salt.

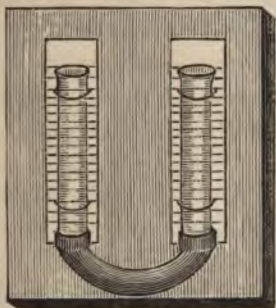

FIG. 41.—U-tube formed by two straight glass tubes, and the band of india-rubber tubing.

Experiment 129.—Fix to the legs of a U-tube slips of cardboard, and either fasten it on a stand or to a thin piece of board. This can be done by boring holes in the card on each side of the tube, and drawing slips of twine or wire round the limbs of the tube; tighten them by twisting the cord or wire, as in Fig. 41.

Divide each scale into 10 larger parts, then each of these into 10 parts; that gives 100. These of course can be still further divided as may be required.

Water must be the standard with which to compare all other liquids. This should be pure distilled water. You can buy a pint at the druggists for one penny. If this is not easily to hand, use water that has been boiled for some time, and allowed to stand and get clear, or filtered rain-water will do.

This standard we can take as 1, 10, 100, or 1000, and is poured in at one limb of the tube; then at the other end pour in the liquid to be compared. Adopt the same plan for pouring in the second liquid as we recommended in Experiment 128, only here it must be a funnel with a long neck, or without this pour the liquid close down inside the tube. The heights must of course be measured from the common surface of the bend of the tube. Supposing 10 inches of water are balanced by 11 inches of another liquid, it is $\frac{10}{11}$ the weight of water; and if 11 inches of water are balanced by 10 of the second liquid, it is $1\frac{1}{10}$ as heavy. Comparisons with milk, oil, sulphate of copper, and other solutions are readily made by this method. For these experiments use glass U-tubes.

If you are giving a demonstration to a class, it is better to provide yourself with three or four of the tubes, rather than to wait for the cleaning out and preparation of the tube between each experiment. The weights of various liquids, when ascertained by this method, can be represented on a table by a series of upright parallel lines, the length of which shall represent their weights compared with water, the length of which shall be the standard.

This will represent what is called in the Education Code, "The Graphic Representation of the Relative Weights of Liquids."

Experiment 130.—Another method of taking the relative weights of liquids is by an instrument called the hydrometer. There are several forms, the simplest is best for our experiments. One may be had for 1*s*., better than we can make for ourselves. It consists of a glass tube with a bulb at the lower end, and below this a smaller bulb, in which some quicksilver is stored; this is sealed in so that it cannot shift from one bulb to another.

We have a sketch of it in Fig. 42. The stem is graduated, the scale running inside the tube. The point at which the stem comes on a level with pure water is 1000.

FIG. 42.

If you wish to make one for yourself, take a clean straight piece of brass wire. Pass the wire through a piece of wood—a block of about 1 cubic inch will do; let this be fixed at about one-third of its length; to the lower end fasten a small bullet to keep it upright and to sink it. Use it first in pure water; mark the point to which it sinks on the wire stem. You can use this with ordinary liquids, but not with strong acids, and it should be washed in warm water after being used, and then rubbed dry.

Pour the various liquids to be tested into glasses, then float the hydrometer in each in succession, read off the point on the stem to which it sinks in each liquid; compare them, and the readings here should agree with the weighings in the last experiment, whether performed by the U-tube or by weighing

the liquids in tumblers. If there should be any discrepancies, find out the reason.

From the experiments in this lesson we learn—

1. That water dissolves very many substances, but not all to an equal extent, and that in some cases a difference of temperature makes a difference in the amount of a substance that water is capable of dissolving.

2. That a saturated solution is produced when water has dissolved as much of a substance as it is capable of doing.

3. That a solution weighs as much as the sum of the solvent and the substances dissolved.

4. That the "buoyant" power of pure water is less than when it holds a substance in solution.

5. That pure water is a good substance to regard as a standard when taking the weights of other liquids.

6. That the weight of a liquid may be gauged by the depth to which a floating body sinks in it, if that floating body is known to float at a certain depth when in pure water.

The following useful instruments are devised on the principles taught by these experiments.

The lactometer, to take the average weight of milk; if it sinks much below the standard, water has been added.

The salimeter, for indicating the percentage of salt in a solution.

The densimeter, to take the weight of a small quantity of liquid; all of which are in form like the hydrometer mentioned in Experiment 130.

LESSON XIV.

WATER A STANDARD OF WEIGHT.

WATER can be used as a standard of weight for solids as well as for liquids.

It is useful to fasten the following table in your memory, at the end of Avoirdupois weight—

1 cub. foot of water		=	1000 oz. or $62\frac{1}{2}$ lbs.
1 gallon	"	=	10 lbs.
1 pint	"	=	$1\frac{1}{4}$ lbs.

Experiment 131.—Fill a tumbler with water, float in it a piece of light wood: some water will be displaced. Remove the wood, fill up the tumbler, float a piece of heavier wood: more water will be displaced than in the first instance, because the heavier will sink further; and if the experiment be repeated with a heavier sample, more water still will be displaced. The pieces of wood used must be equal in size. The glass should stand on a plate, and the water that runs over in each case poured into test-tubes of the same diameter, say $\frac{1}{4}$ inch for this purpose; the quantities of water can then be compared. To show that the quantity of water displaced in each case is equal to the weight of the floating wood, try the following experiment.

Experiment 132.—Bring out your scales once

again. With very fine wire attach a sling to the bottom of one of the scales, or it is better if you attach a counterpoise and remove this scale-pan.

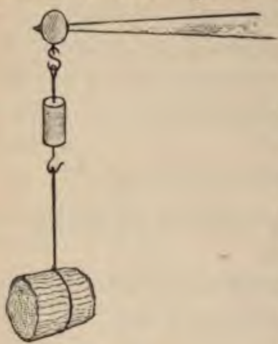

FIG. 43.

Fig. 43 shows a piece of lead, to which a hook is attached above and below. To this substances can be suspended. See that the scale and counterpoise balance. Now suspend the wood, as shown in Fig. 43, and balance it with small weights; arrange the scales so that the piece of wood can float in the tumbler of water. The wood apparently loses weight at once, when it touches the water. The scale with the weights, that before balanced the wood, is now too heavy. Take out some of the weights, so that the wood can float freely, collect the water that is displaced by the wood, pour it into the scale from which it—the wood—is suspended, replace the weights, and now they balance as before, although the wood is floating, the small quantity of water making all the difference in regard to weight. Repeat the experiment with each of the pieces used in the former experiment.

Now we will try similar experiments with substances that do not float in water, but which do not dissolve in water.

Experiment 133.—Fix up your scales as in the last experiment. Suspend at one end a piece of metal, say a penny piece, and twist a very fine wire round the rim—do not put a hole through the coin—

the wire the "flower-girls" use is useful for this purpose. When suspended, weigh it accurately. Now bring up the tumbler so that the coin can be suspended in the water; the weights, although they balanced the coin at first, will now be too heavy, the penny piece really seems not to weigh as much as it did at first. Remove enough weights so that a balance is again restored. Note how much less it weighs in water. Now work out a little sum. Suppose the coin weighs in air when first balanced 160 grains, but when weighed in water it weighs only 140 grains; apparently it has lost 20 grains in weight. Now divide 160 by 20 and you get 8. We say that the specific gravity of the coin is 8, *i.e.* the metal is eight times as heavy as water.

Try a similar experiment with a shilling, a piece of lead, zinc, brass, building stone, chains, and other substances. Compare your results with a list of specific gravities given in any standard science book.

Experiment 134.—Take a strong glass tube, close one end up with a good cork, make a plug to fit it. Partially fill the tube with water, push in the plug, put the stopped end on a firm table or block, and by pushes and blows try to squeeze the water into a smaller space. How unlike the pop-gun experiment, where you were able to squeeze up the air into a much smaller space.

Look up a drawing of the hydraulic press, and see how useless this machine would be if the water were compressible.

Experiment 135.—Take a U-tube, partially fill it with water, incline and turn it in various directions and notice that the two surfaces are level, and if a

line were drawn at the top of the water in one arm of the tube and carried on to the other, it would be a straight line. In other words, liquids in open vessels always keep a level surface.

Experiment 136.—Take a wide tube, put a well-fitting cork into one end, bore a hole through this, to which fit a smaller tube; attach to this a length of india-rubber tubing, into which fit a very small glass tube (Fig. 44). Now fill the large tube while some one else holds the other end. Form it into a

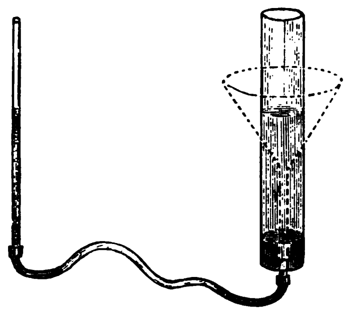

FIG. 44.

U-tube, or curve it about in any way, a level is maintained in the two tubes, though one tube carries considerably more water than the other.

Substitute a large funnel for the larger tube, the result is the same.

Explain from this experiment how water is supplied in large towns from the reservoir by means of mains, branch-pipes, and the smaller pipes fixed in houses, and so carried to various floors in the houses.

Experiment 137.—Attach to the india-rubber tube used in the last experiment a small tube, the end of

which has been drawn to a fine jet. Put the other end in connection with a tub or a large flower-pot, put it on some high shelf, fill the vessel with water, uncover the jet, and you will have a pretty little fountain, the height of which will be regulated by how much it is kept below the level of the water in the supply-vessel.

Look at the coffee-pot or tea-pot, in which the small quantity of liquid in the spout of the vessel stands at the same height as that in the body of the vessel, in other words balances it.

Experiment 138.—Take again a U-tube, fit to each arm a cork, attach a stout wire to each, extending upwards, on the top of which fix a little shelf, as in Fig. 45. Now put some water into the tube, reaching about half-way up, put an ounce weight on to one of the shelves: the plug resting on the water in the opposite leg of the tube will be pushed upwards. Place more weights on it, you will find that no weight less than that on the other plug will balance it.

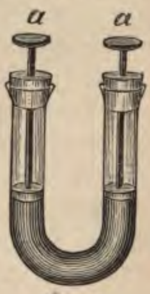

FIG. 45.

Experiment 139.—Take a glass tube open at both ends, and a tall glass jar; cut a piece of wood or cork that will easily slip through the tube. Float the wood, close one end of the tube by pressing the thumb over it, place the lower end of the tube over the floating wood, push the tube down into the water: the wood goes down, although still floating. When it gets to the bottom of the jar remove the thumb: up rushes the water, bringing the wood with it. Repeat the experiment, using a small glass ball,

i. e. one which easily runs up and down the tube. Place it in a jar of water, push down the closed tube as before. When it covers the ball, remove the thumb; the glass, although much heavier than water, will be brought up into the tube some considerable height.

These two experiments clearly show that water exerts a pressure upwards.

Experiment 140.—Repeat the above experiment with a glass ball too large for the tube. Place the tube over it as before; when firmly placed in contact with the glass ball, remove the thumb and lift the tube: the ball will be held tightly against the tube by the upward pressure for some time.

From this lesson we learn—

1. That water is uncompressible, although its particles move so freely among each other that it takes the form of any vessel into which it is placed.

2. That it maintains its level, which is due to its exerting pressure equally in all directions.

3. That this pressure increases according to its depth.

4. That water has a buoyant power, so that substances weighed in water apparently weigh less than in air.

5. Water may be used as a standard of weight for solids as well as for liquids.

6. That when a solid floats in a liquid, it displaces as much in weight as is equal to its own weight.

7. When a body heavier than a liquid is suspended in that liquid, it has an upward pressure equal to the weight of the liquid it displaces.

8. We speak of Absolute and Relative Weight.

The first is used when we speak of a substance weighing so many pounds, ounces, or grammes, and the latter when we refer to its specific gravity, or how much it is heavier or lighter than water.

Note, in reference to our table of French weights, that 1 gramme of water is 1 cubic centimetre. The volume and weight of solids may be conveniently expressed in one term.

Great use may be made of the specific gravity of a substance to tell the weight of a given volume; *e. g.* a block of building stone is 3 ft. long, 2 ft. thick, and 1 ft. 8 in. broad. What is its weight? We find by experiment its specific gravity by chipping off a small piece of the stone. Suppose this is $2\frac{1}{2}$.

By multiplication $3 \times 2 \times 1\frac{2}{3} = 10$ ft., the cubical contents of the stone.

$62\frac{1}{2}$ lbs. = weight of 1 cubic foot of water; the stone is $2\frac{1}{2}$ times this;

$\therefore$ $10 \times 62\frac{1}{2} \times 2\frac{1}{2} = 1562\frac{1}{2}$ lbs., or the weight of the block of stone.

LESSON XV.

HOW WATER GETS TO BOIL.

In this lesson our experiments will deal with effects of heat on water.

Experiment 141.—Take a Florence flask, fit it with a good cork, through which bore a hole for a glass tube of fine bore; let this be about 12 inches long, as in Fig. 46. The cork and tube must fit well. Fill the flask with water which has been standing in the room for a short time, so that it is somewhat warmer than when drawn from the tap. If you want to show the experiment to a number of persons, it is best to put a little red or blue ink to colour the water. The flask must be full, and the tube partially so, and the height to which it stands marked. Now—being sure that the cork fits well—the water is shut up in the flask, and can only get out by way of the tube. Put the flask into a jar or basin of ice and water. The water in the flask will soon be cooled by this bath, and it will show the effects of the cooling by shrinking

Fig. 46.

into a smaller space; the liquid will sink down the tube towards the flask; watch it till it becomes stationary, then mark the point to which it sinks. Take it out, and in the air of the room it will soon come back to its old place in the tube. When in this condition, put it into a jar containing some warm water, or better still put it into a jar, and pour warm water on it gradually. Let it be gradually—and the water not too hot, or the flask may crack. Increase the quantity of hot water, and watch the rise of the liquid in the tube, it will soon get to the top. Before it reaches this point take it out, and expose it to the air again, and gradually the water will go back to its old level in the tube.

What would be the effect if water filled a closed vessel, and the water were then heated?

In this experiment, water first contracts on being cooled, and expands on being heated. It is the same with water in all places, but when you can cork up a small quantity in a flask, you can better see what actually happens. Before we go any further we must introduce the thermometer, if we want to measure accurately the rise and fall of temperature.

Fig. 47.

Experiment 142.—Take a thermometer, get one of such make that the bulb of the instrument only is dipped in a liquid when used. A chemical thermometer costing about 1*s.* 6*d.* (Fig. 47) will suit best for these experiments, although an ordinary thermometer mounted in the usual manner is best for noticing the rise and fall of temperature in a room day by day. *Now repeat* the experiment with the ice-water

and warm water, as in the last case. In a thermometer the liquid generally used is quicksilver, and on the side of the tube numbers mark certain divisions called degrees. In the ice-water the point reached by the quicksilver will be marked 32° if the Fahrenheit scale is used, and 0° if the Centigrade scale is used. These points we will explain a little later on. The special point we want you to notice is this: that by means of a thermometer we can tell how much one quantity of liquid is warmer than another; but with the flask, where no scale is attached, you cannot. You can only say it is warmer, but not how much warmer. We cannot, by the mere feeling with the hand, tell how much one body is warmer or colder than another; therefore we must have an instrument that we can depend on to do this for us, and this is the thermometer. A thermometer is a measurer of temperature.

Experiment 143.—This will help us to see how incapable we are of judging how much one substance is colder or warmer than another. Take three dishes; into one put some water, with some pieces of ice in it, into another put some water as hot as you can bear your hand in, into a third put some lukewarm water. Now place one hand in the ice-water and the other in the very hot; hold them there for a short time, then place both hands together in the lukewarm water. To the hand removed from the ice-water this will feel hot, but to that removed from the hot water it will feel cold. One hand, then, says the water is very warm, but the other says it is cool. Now with the thermometer we can tell the exact condition of things.

Experiment 144.—Fix up a flask in the ring of a retort-stand, put in some water, and boil it; lower the bulb of the thermometer into the steam. Fix it, so that it is kept there some little time. Watch the quicksilver; it rises to a certain point, marked the boiling-point, and it never rises higher than this point in water boiling in the open air. This is why it is called the boiling-point of water. In melting ice the quicksilver sinks to the same point which is always called the freezing-point of water. Between these two standard points, the space is divided into an equal number of parts called degrees, marked °. In the Fahrenheit scale the freezing-point is marked 32° and the B.P. 212°, and the space between the freezing and the boiling-points is divided into 180° equal parts. In the Centigrade scale the freezing-point is marked 0°, and the boiling-point 100°.

Experiment 145.—Fit a flask similar to that used in Experiment 141 with a good cork and bent tube, fill the flask and the tube with water—the central portion of the tube may be of india-rubber, but it must not be bent so that there is a kink in it. Fix the flask in a ring on the retort-stand, and put the other end under the mouth of an inverted test-tube filled with water, as in Fig. 48. Heat the flask, and bubbles of air will soon be given off from the water, and will collect in the test-tube. This shows that at ordinary temperatures water contains a large quantity of air and other gases, which are given off when it is heated. The singing of a kettle is due to the escaping of the gas.

Experiment 146.—Boil some ordinary tap-water

for some time, till all the air is boiled out of it, then let it cool. Probably some lime or other substances will settle at the bottom of the flask. Taste the water when it gets cold; contrast its taste with that of freshly-drawn tap-water. The flat taste of the former is due to the air being driven out of it. Pour some of it backwards and forwards through the air a few times, then taste; it will be somewhat improved, having absorbed some air from its exposure.

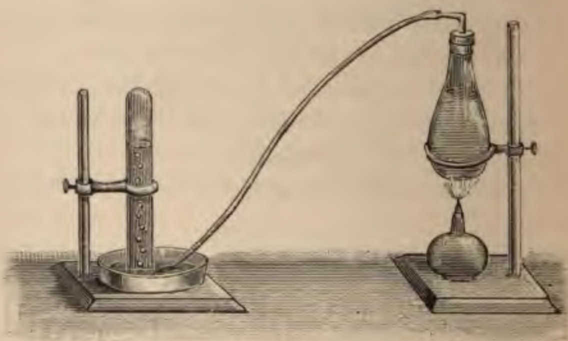

FIG. 48.

Experiment 147.—Take a flask, half fill it with cold tap-water, put in a few clippings of blotting-paper, which will settle at the bottom of the flask. Now heat it from below. The lower layer of water will soon become warmer than the layer above it, and will therefore rise, while colder water will take its place to be warmed in its turn, and will rise, and so on till all the water reaches the same temperature, which will not be till it boils. The paper moves with the layers of water, so you are able to watch

the whole process. When it boils, bubbles will still rise from the bottom of the vessel; but these are bubbles of steam.

Experiment 148.—Place a lump of ice in a tumbler of water; the ice will chill the upper layer, and it will sink, a lower layer rising, the process of the last experiment being reversed. If held up to the light, the falling of the layers can be seen, till all the water becomes the same temperature.

Experiment 149.—Take a test-tube, $\frac{1}{2}$ inch by 6 inches will do, fit to it a cork—not to fit too tightly—fill with water to about one-third of the length of the tube, slip the cork half-way down. Boil the water, steam will soon come off freely and force upwards the cork. Remove it from the flame, chill the upper part of tube with some blotting-paper soaked in cold water. The steam will condense and the cork go back again. Repeat the heating and then the cooling. You have seen a proof of the elasticity of steam, and of its change back again to water on being cooled.

Experiment 150.—Fit a very good cork to one of your Florence flasks, put into the flask a small quantity of water, twist a cloth round the neck of the open flask, hold it over the flame of a lamp till it boils rapidly and steam comes off freely. Then slip in the cork and remove the lamp, put the flask down gently, and cork it securely. The water will stop boiling. Hold it up, still with the cloth round the neck, pour on the flask some cold water. Boiling begins again, and rapid boiling, which, if the flask has been well corked, will go on for some time.

This shows that water will boil at a lower temper-

ature, if the pressure of the air is taken off from its surface.

The result of this experiment is a puzzling one to young folks when seen for the first time, for it seems so strange to see "water made to boil by putting cold water on it."

If you could put a thermometer into the flask, you would find the temperature much below the boiling-point marked on the scale. The B.P. on the thermometer scale means, as we mentioned before, the temperature at which water boils in the open air at the surface of the sea.

In your experiment you drive most of the air out by boiling the water, which, in giving off steam, clears the air out of the upper part of the flask. When you cork it up, it is done so quickly that very little air gets back again. The flask has steam only to exert a pressure on the water. When the cold water is put on, the steam is condensed, and the pressure is therefore taken off, so that the water boils again. A similar experiment can be shown by means of the air-pump, which enables you to take pressure off the surface by pumping air out of the receiver. Before uncorking the flask, shake it; the water seems hard and to fall back like a hard substance, not at all like a liquid; this is because it is deprived of air.

From this lesson we learn—

1. *That a given volume of water expands or increases in bulk on being heated, and contracts on being cooled.*

2. *That temperature can only be taken by a reliable instrument, such as a thermometer, and that the senses cannot be relied on for accuracy in judging differences of temperature.*

3. The standard points on a thermometer are the freezing and boiling-points of water at ordinary pressure at the sea-level.

4. That when the pressure on the surface of water is lessened by any means, it boils at a lower temperature, and when the pressure is increased the boiling-point is raised. At the bottom of a deep coal-pit, for example, water must be raised to a higher temperature than 212° Fah. or 100° C. before boiling, while at the top of Mont Blanc it boils much below the marked boiling-points.

5. That the Centigrade and Fahrenheit scales are only different ways of marking degrees on the thermometer, and that as 100 divisions in C. = 180 divisions in Fah., it is easy to render the readings from one to the other. Let us take one example. Supposing we have 75° C. and we wish to compare it with the Fahrenheit scale.

As 100° C. = 180° Fah., or 5° C. = 9° Fah.—
we multiply 75 by $\frac{9}{5} = 135$; but Fah. 32° agrees with C. zero; we therefore add 32; so that $135 + 32 = 167°$ = the reading on the Fahrenheit scale of 75° C.

To reduce 197° Fah. to C. First subtract 32; thus $197 - 32 = 165$, and as 9° Fah. = 5° C., multiply $\frac{165}{1} \times \frac{5}{9} = 91\frac{6}{9}°$ or 91·6° C.

6. That all ordinary water contains air and gases in solution. The presence of these gases probably assists in breaking the continuity of the water, and so helps it to boil, for water out of which the air has been expelled is difficult to boil, and does not boil till it reaches 60° or 80° above the normal boiling-point, and does so with an explosive violence.

7. That, under ordinary conditions, water can get

no hotter than its boiling-point, and if heat continues to be applied the water is changed into steam, the elastic force of which can be used for doing work, as in the steam-engine.

8. That the process by which water becomes heated is called convection or conveyance, because the particles warmed at the source of heat travel upwards among the cooler particles and convey the heat to them, till they are equally warmed.

Convection currents exist in the ocean and in the air. The Gulf Stream is a convection current. The trade-wind is a convection current.

LESSON XVI.

WATER AND ICE.

YOU can get a lower temperature than the freezing-point of water, by making what is called a freezing-mixture.

Experiment 151.—Make a freezing-mixture by pounding together two pounds of ice and one pound of common salt. Do this in a wooden bowl if you have one, and stir them with a wooden spoon. When intimately mixed, put in the thermometer; you will find the temperature very much below freezing-point. Be careful how you bury the thermometer in the mixture, for the bulb is very thin. You may get this mixture sometimes down from 16° to 21° below freezing-point, it depends very much on how it is mixed. Having taken its temperature, cover up the mixture with an old woollen cloth, and put it aside for the next experiment.

Experiment 152.—Take two small bottles—"doctor's phials" will do—fill them quite full of water, cork them with some sound, soft corks, tie these in securely. Bury them both in the freezing-mixture, stand them aside, cover the whole with flannel or baize as before. In a short time you will hear a sharp crack; then take out the bottles,

both of which will either be broken or the corks forced out, by the water in them being changed into ice. For water not only expands on being heated, but it expands on changing into ice. Examine the bottles well. Now you can explain why water-pipes burst when nipped by "Jack Frost." Some persons think pipes are broken when a thaw sets in. Iron bottles, iron shells of great thickness are burst almost as easily as the glass.

Experiment 153.—Take the ice from the broken bottles and put it on to the water—it floats; this is another illustration of ice being lighter than water. Look at the floating ice, thoughtfully trying to make up your mind as to the proportion above and below the surface of water.

Note.—One volume of water at 4° C. becomes $1\frac{1}{11}$ volumes as ice, therefore when ice floats, $\frac{1}{12}$ of its volume is above the surface of the water.

Water in cooling contracts till it reaches a temperature of 4° C., when cooled to 3° it expands again, and so on till it gets to 0°, then it suddenly changes to the solid ice.

Experiment 154.—Put some ice and water into a flask, let it stand till the temperature is down to 0° C., then put in a few more pieces of ice. Fix the flask into a ring on the retort-stand. Suspend the thermometer in the flask so that its bulb comes into the mixture. Now place a lighted lamp under the flask; watch the thermometer; note that it shows no rise in temperature till the whole of the ice is melted.

Experiment 155.—Take several pieces of ice, bring their smooth surfaces together, press them together, giving them at the same time a twist; they will

freeze into a chain of pieces. Take two or three larger lumps of ice, and perform this experiment under the surface of warm water. The result will be the same.

Experiment 156.—On a sunny day put out a lump of ice where the sun's rays fall on it. Place on the top of it some dark-coloured stones. The stones will soon become embedded in the ice.

Experiment 157.—Cut a slab of ice, hold it in the sun, so that it begins to melt; have at hand a good magnifying-glass. Examine the surface. You will see, just under the surface, some little bright spots; these are spots where the ice is beginning to melt, and are empty bubbles. From these centres you will notice some six-sided flowers, arranging themselves around these, like petals around central stems. The ice-flower is six-petalled.

Experiment 158.—Chip a piece of ice into the shape of a double convex lens. To get its surfaces smooth use a folded cloth dipped in warm water. When the sun is shining take the ice-lens, use it as a burning-glass, set fire to a piece of brown paper, or fire a small quantity of gunpowder.

Experiment 159.—Fix a slab of ice into a hollow in a piece of wood, put it flat on the table. Fix a second piece into another piece of wood, so that you can rub the two pieces of ice together without touching them with the hands. They will soon begin to melt.

Experiment 160.—Take a block of ice of 2 lbs. or 2½ lbs. weight. Support it at the ends on two chairs or tables. Put a piece of wire across it, and suspend from it a weight of 7 lbs. or 10 lbs. The wire gradu-

ally becomes embedded in the ice, and works its way through it, so that the weight will be dropped, the ice re-forming at each stage, so that the ice is intact and forms as solid a block at the end as it did at the beginning of the experiment. You can however generally see a ridge where the wire passed through but the re-freezing is quite perfect.

This and also Experiments 155 and 156 are due to what is called Regelation, and so is also the moulding of ice into various shapes under great pressure. This also accounts for the motion of glaciers.

From this lesson we learn—

1. That water reaches its minimum density at 4° C., gradually expanding till it reaches 0°, when it changes into ice. Ice is lighter than water in the proportion 11 to 12. Icebergs and other ice masses therefore float, and for every 100 feet above water we may at least say that they are 1000 feet below water.

2. That the force of expansion is so enormous that strong containing vessels are broken. By means of frost the rocks at the surface of the earth are split up and broken. The same thing happens to soil; this is an inducement for the farmer to plough before the frosts set in.

3. That ice may be melted by pressure, but that the liquid may immediately re-freeze.

4. That heat may pass through ice without the ice greatly absorbing it; ice may therefore act as a lens.

5. That heat sufficient to melt ice may be caused by friction. That even ice gives up its heat in *dissolving* salt, enabling freezing-mixtures to be *made* much below the ordinary freezing-point of water.

LESSON XVII.

NATURAL AND PURE WATER.

WATER is such an important subject, that a few more experiments with it will not be out of place, and it will give a degree of completeness to this branch of our subject.

Experiment 161.—Take a rectangular dish, put into it a weighed quantity of water. After 24 hours weigh again the water that is left. In the meantime the dish may be stood in a room, in the sun outside, or in a shed not exposed directly to the open.

Find the area of the dish, find the loss of weight in the water, calculate from this what a square yard, acre, or mile would lose under the same conditions. You may thus form some idea of the quantity of invisible vapour that is carried away from the surface of the ocean by the air in a given time. This quantity is increased when the air is moving quickly, as in a wind.

Experiment 162.—Fit a flask with a tube passing through a cork, and bent as in Fig. 49, and passing into a larger tube attached to a second flask. Fix the first flask to a ring of the retort-stand, the second to lie in a basin of cold water, and a strip of calico or something of the kind loosely wound round

the outer tube. This must be kept cool by dripping water, or by having water put to it frequently. Boil the water; the steam will collect in the narrow tube, pass over into the wider, where it will be condensed to a liquid, and run down into the cool flask as distilled water. This will furnish you with a specimen of pure water. Taste it, convince yourself that pure water is not pleasant to drink.

Experiment 163.—Take three saucers, put into

FIG. 49.

one a quantity of distilled water, into another the same quantity of tap-water, and into a third the same quantity of sea-water. Put them out in the open air for evaporation as before. When the saucers are left dry, examine what remains as dry matter; the distilled water will leave nothing, the tap-water probably not much, the sea-water some crystals of salt and other substances.

Experiment 164.—If your specimen of tap-water leaves much lime, it is a proof that it is what is called hard water. Take less than a quarter of a pint of this water, put it in a clear glass bottle, and

into a similar bottle the same quantity of distilled water, or water that has been boiled for some time. Put into each a small shaving of soap; shake up the bottles. The soft water, or distilled water, will show a lather on the surface almost at once; not so the hard water. This experiment shows why hard water is not economical for laundry and other washing purposes.

Boiling hard waters softens them; the substances held in solution are thrown down by boiling, as shown by Experiments 163 and 164.

Experiment 165. — Some substances are much more readily dissolved in water than others, also in larger quantities. Take four equal quantities of distilled water, and weigh out equal quantities of salt, soda, chalk, and sugar; put each into one of the quantities of water. We use distilled water, or water that has boiled for some time, so that nothing is already in solution when the substances are put in. Shake up the solutions; some will be clear, showing that all the solid added has been dissolved. To those that are clear add more of the solid, little by little; when the water has dissolved all it is capable of doing, any additional substance will settle. Take note of the weights of the substances these equal volumes of water have dissolved, compare them by weight, and calculate the amount of solid per cubic inch or cubic centimetre. This will help you to understand why some waters are harder than others—it is according to the nature of the soil through which they filter. Remember also that the soluble power of water is increased by the carbonic acid gas it absorbs in falling through the air as rain.

When water of this sort is boiled, you proved in Experiment 145 that carbonic acid comes off with the gases; the water, then, cannot carry in solution much lime, which is thus deposited at the bottom of the vessel in which it is boiled.

Experiment 166.—Foul water may be very much improved by filtering it through animal charcoal. Colour a little water, either with purple cabbage, with litmus, or log-wood, put it into a flask, add some bone-black to it, shake it up, and then run the mixture through ordinary filter-paper: the water will come through almost colourless. Freshly-burnt charcoal will deprive water of poisonous impurities.

Experiment 167.—Distil in succession some infusions of tea, coffee, soap, and beer; note what is left in the flask, take the densities of the distillate, *i.e.* the substance that passes over with the water into the second flask.

Experiment 168.—Take equal quantities by weight of water at ordinary temperatures of the air, and boiling water. Take the temperatures of each with the thermometer, then mix them together. Then take the temperature of the mixture with the thermometer; see that it agrees very nearly with the calculated temperature obtained thus: 1st sample, temperature 10° C.; 2nd sample, equal quantity, at 100° C. Result: double quantity at $(100°+10°) = 110 \div 2 = 55°$ C.

Perform this experiment as quickly as possible; stand your glasses on pieces of flannel, and wrap flannel round them, so that the temperature goes down as little as possible when performing the experiment.

Experiment 169.—Take half-a-pound of dry ice

and half-a-pound of water at 80° C., mix them together; when the ice is melted take the temperature. By the results of Experiment 168 what do you expect the temperature to be? The thermometer tells you it is 0° C.

Experiment 170.—For the last experiment in this series let us take a pretty instance of freezing water by evaporation. Take two watch-glasses, and a spoonful of ether. Dip one of the glasses into cold water, place its convex side into the hollow of the second glass, put a spoonful of ether into the hollow of the upper glass. Blow through a tube at the ether, which will evaporate so quickly that the moisture between the two glasses will be frozen. Lift the upper, the lower will come with it; crystals of ice may be seen between the two. When they get warm the ice melts, and the lower will drop from the upper glass.

From this lesson we must be able to give answers to the questions—What is evaporation? What is boiling? These are the two methods by which water is changed into vapour. Evaporation takes place at all temperatures, and is a slow method by which water passes off into vapour. The particles at the surface of water are loosened out, these particles are dissipated in the air. Evaporation goes on faster when the temperature is raised.

Boiling cannot take place till the pressure of its vapour is equal to the pressure of the air. Bubbles of vapour rise from the body of the liquid, and not from the surface only; while evaporation takes place only from the surface.

From this series of experiments we learn that—

1. Evaporation takes place from the surface of a liquid, and if exposed to air for a sufficient length of time the whole of the liquid disappears, leaving behind whatever solid may have been in solution.

2. That on boiling a liquid and re-condensing its steam, we get a pure or distilled liquid.

3. That hardness in water is due to substances being dissolved in it; these are obtained from the earth through which it filters.

Water is said to be temporarily hard when it can be softened by boiling, permanent hardness being that which cannot be got rid of even by prolonged boiling.

4. That water has different powers of solubility for different substances.

5. That the mere running of water, as in a river, wears away its bed, and carries finely-divided matter to the sea.

In speaking of the Thames, Prof. Huxley says, in his *Physiography*—"Imagine a huge die-shaped mass of stone, measuring 100 feet in length, 100 feet in width, and 100 feet in height; this would contain one million cubic feet. No fewer than fourteen of these gigantic cubes appear to be quietly stolen from the surface of the Thames basin by means of running water, and transported to the sea, in the course of a single year."

6. That to change ice into water it requires its own weight of water at a temperature of 80° C. If we call each degree a unit, we can say it requires 80 units of heat to change ice into a liquid.

Note.—One cubic inch of water forms nearly one cubic foot of steam.

LESSON XVIII.

INFLAMMABLE AIR.

WE have learnt a good deal about water from our experiments, but we have learnt nothing about its composition. We will now undertake a few experiments that will help us to information in this direction.

Experiment 171.—As a preliminary experiment we want you to learn something about an acid. We will take sulphuric acid, sometimes called "oil of vitriol," or simply "vitriol." It must be used very carefully, kept in a stoppered bottle, and for ordinary use keep small quantities of it. Do not let young people get to it, do not drop it on your hands, or pour it so that it splashes up into your face or on to your clothes. It burns badly. Should you get any on to your hands or face, use at once plenty of cold water; should you get any even dilute on to your clothes, use at once some strong ammonia on the spotted parts.

Take a small quantity of water in a beaker, half-an-ounce is sufficient, pour in gently some sulphuric acid; when nearly equal quantities of each are mixed, the beaker will become very hot, as hot as boiling water. Prepare a test-tube with a cork and jet, as in

Fig. 50. Put into the tube half-a-spoonful of ether, put in the cork with the jet, plunge it into the mixture of acid and water. Notice the ether, it boils, and rapidly; put a lighted match to the top of the tube, something catches fire and burns vividly. This is the ether vapour. So it will go on as long as any ether remains.

FIG. 50.

Strong acid and water mixed together give off immense heat. We must remember this, for we may often have to mix the two.

Experiment 172.—Make a solution of litmus, take a portion in a wine-glass, dip the tip of a slip of wood into the acid mixture of the last experiment. Now put it into the litmus and stir it up. Notice what happens; its colour is changed from blue to red. This litmus is a very delicate test for an acid. Now take a drop of ammonia, let it drop from the lip of the bottle into the reddened litmus; back it comes to its first colour—blue.

It is useful to remember that litmus is a very delicate test for an acid. Have some always at hand for this purpose. Reddened litmus is an equally good test for an alkali like ammonia.

Experiment 173.—Fit a bottle with a good cork and tubes, such as shown in Fig. 51, one tube passing down to the bottom of the bottle, the other just through the cork and bent into an L; to this attach a foot or so of india-rubber tubing, and to it a small piece of glass tubing, to keep the elastic tubing out. Get some odd bits of zinc, clip them into small pieces,

or if you have no shears get it done for you. Put some of these clippings into the bottle, just cover them with water, then put in the tubes as shown. Now get a dish, fill it half full with water; a couple of bottles, fill them with water, and invert them in the dish of water, according to directions given for collecting oxygen in Fig. 36. To do this cover them over with a glass plate or card, for they must be quite full of water, no bubbles of air with it. Now put the end of the "delivery-tube," *i. e.* the india-rubber tube

FIG. 51.

with glass tip, under the water. Pour some of the acid mixture used in Experiment 171 through the funnel of the "safety tube" into the bottle. An active bubbling will be the result, and bubbles will escape freely from the delivery-tube through the water. Fill a test-tube with water, hold its mouth over where the bubbles are coming off; the water will soon be displaced by gas. Try the gas so collected with a lighted taper. It will most likely explode, but as there is a small quantity there is no danger.

Repeat the operation till you get a tube of gas that burns quietly with no sign of an explosion. When this is so, put the delivery-tube under the mouth of one of the bottles. Let this remain till the bottle is full of gas, then slide it aside, and collect a second, and so on till you get three or four bottles. Should the gas come off rather slowly, put in a little more acid mixture, this will hasten it. Having collected all the gas you require, try

Experiment 174 on the gas itself. At the tip of the delivery-tube, from which be sure that gas is still coming off, bring a lighted taper: the gas burns. The gas is sometimes called inflammable air. Notice how it burns, with very little light. Hold a glass jar over it, the inside soon becomes moist, moisture will trickle down the sides. This reminds you somewhat of the experiments where you held a jar over a candle-flame, a lamp-flame, a coal-gas flame. Let a few drops trickle into a little litmus mixture; it does not change it, so it shows there is no acid in whatever is produced—in this it is unlike the candle experiment. Twist a little coil of fine iron wire, hold it in the flame, it will soon be heated red-hot. If you have a piece of platinum wire, try it as well. Here we have a gas that burns, and yet it comes from water.

Experiment 175.—Attach a short piece of taper to the end of stiff wire, light the taper, take a jar of the gas, hold it mouth downwards, push in the lighted taper. Notice particularly what happens—the taper is extinguished, but the gas in the bottle is burning. How different to the other gases in our former experiments.

Draw the taper back again slowly, it will re-light

when it gets to the mouth of the jar where the gas is burning. Notice the colour of the flame, and how it creeps along in the jar. When it is all burnt, notice the inside of the jar. It is quite wet.

Why did we ask you to hold the jar mouth downwards? We will answer this in the next experiment.

Experiment 176. — Take a bottle containing ordinary air, but about the same size as the bottles containing the gas; hold the air-jar mouth down-

FIG. 52.

wards, with a paper hood on the off-side; bring the mouth of one of the bottles containing the gas to the mouth of this jar, and slowly turn the jar down, as in Fig. 52; then hold them upright, mouth to mouth, for a short time. Then stand the lower bottle down, put a lighted taper into the upper bottle, hold it tight, for there will be a slight explosion, and the gas will take fire, showing that most of the gas was poured upwards from the lower bottle, proving how much lighter it is than air. Put a lighted taper into the bottle you have put down, and which

first of all contained the gas. Nothing happens, except the taper goes on burning as it does in air. This shows that all the gas with which you first filled it has gone.

Experiment 177.—Take a large paper bag, made of very thin, light paper, draw up the mouth of the bag with a piece of thin twine or thread round the end of the delivery-tube, keeping the sides flat meanwhile, so that the least possible quantity of air can lurk about inside the bag.

Now put on to the zinc a little more of the acid mixture, and the gas will come off fast, and soon fill up the bag. The bag will be uneasy, and when quite full, if you unfasten it from the delivery-tube, it will most likely sail away to the ceiling of the room. Small balloons made of gold-beaters' skin, or of collodion, are sold specially for this experiment.

War balloons are generally filled with this gas. Ordinary balloons, which are much larger, are filled with coal-gas, which is much heavier. The first balloon was filled with warm air.

The gas made from acid and zinc mixture in these experiments is less than a fourteenth of the weight of common air.

Experiment 178.—Take an old-fashioned soda-water bottle—see that it is sound—put into it some zinc clippings, put a good cork into it, but bore a hole through the cork about the size of an ordinary lead pencil. Remove the cork, put in some acid mixture; again put in the cork, hold the bottle aslant, with cork pointing towards the ceiling. Hold the bottle tightly, and a lighted taper near the mouth of the bottle. A loud explosion will soon take place, shoot-

ing out the cork with considerable violence. Note the gas by itself burns quietly, but when mixed with air it explodes.

Coal-gas mixed with air explodes. Whenever gas is found to be escaping, the source should never be looked for with a light, or an explosion—sometimes a very dangerous one—is sure to result. The nose is generally a very good guide to the source of mischief. Should gas escape into a room, open doors and windows, and on no account take a lighted candle or lamp into the room till the mischief is remedied, and the room clear and sweet.

Experiment 179.—Bring out once again the apparatus for making oxygen, unless you have a small supply at hand. Empty out your mixture from the soda-water bottle, fill it with water, invert it in a dish of water, put in oxygen till it is one-third full, fill up the rest with the gas obtained from the zinc-and-acid bottle, put in the cork used in last experiment. Then bring it out into the air, hold the mouth pointing upwards as before, bring a lighted match or taper to the hole in the cork—an explosion more violent than the last will follow. Notice the inside of the bottle, it will be covered with moisture, as in all experiments where this gas is burnt. This gas is called hydrogen, and means the "water-producer," because whenever it is burnt, water is formed.

Hydrogen can be prepared in several ways, as we shall see later on; but the plan we adopted from the zinc-and-acid mixture is the simplest.

Experiment 180.—Fill a bottle with carbonic acid gas, stand it on the table, and invert upon it a bottle of hydrogen, leaving the mouth of each bottle open.

After a few minutes test the upper bottle with lime-water. You will find some of the carbonic acid gas has crept up into the bottle, although it is so much heavier. How much heavier is carbonic acid than hydrogen? Let us see. Air is $14\frac{1}{2}$ times as heavy as hydrogen, and carbonic acid $1\frac{1}{2}$ times as heavy as air. $14\frac{1}{2} \times 1\frac{1}{2} = 22$ nearly. Carbonic acid is therefore 22 times as heavy as hydrogen.

Hydrogen is the lightest substance known. The weights of gases are generally compared with it, as the weights of liquids and solids are with water. The weights of atoms—although we have never been able to separate an atom—are compared with this gas, and it is said to be 1, and oxygen 16, because it is sixteen times as heavy.

We learn from this lesson—

1. That acids and alkalies have opposite actions or properties, and that the action of one may be neutralized by the action of the other.

2. That by the action of sulphuric acid, zinc sets free hydrogen gas from the water.

3. That hydrogen burns, but will not allow substances to burn in it. That when hydrogen is burnt in air, water is always formed.

4. That water consists of two gases, oxygen and hydrogen.

5. That when hydrogen and oxygen are mixed and a light is applied, they unite with explosive violence.

6. That hydrogen is very much lighter than air, and is therefore used for inflating balloons.

7. That gases diffuse among each other irrespective of their weights. This property in gases accounts in a great measure for the uniformity in the composition of the atmosphere.

LESSON XIX.

WHAT CAUSES HEAT?

We are in this lesson going to try some experiments which will help us to learn something about Heat. Heat does so much in the world, that we ought to know how some of its effects are brought about.

Experiment 181.—Take a piece of stick, get it well alight, plunge the lighted end into a wide-mouthed bottle. Notice what happens. From former experiments, you are not surprised to see that the portion in the bottle soon stops burning; but close to the mouth, and outside the mouth of the bottle, it goes on burning. You know why it does not continue to burn in the bottle. Withdraw the stick, blow out the blaze. Examine the portion that has been burning, compare it with the unburnt part. It is charred, it has lost its form, it has become lighter than the other end, and covered with a hard, black, scaly coat. The lightness is caused by a part of the stick combining with the oxygen in the air, which disappear, but form such products as we found resulted from a burning candle. Where did the heat come from?

Experiment 182.—Take a piece of hard dry wood, cut it into a rough cedar-pencil shape, round off

one end, grasp it firmly in the hand, and rub this end hard and quickly along the edge of a piece of wood of the same kind. Have a tiny piece of phosphorus ready, lying on a piece of tile or slate. After rubbing this stick for a short time, bring the end so as to touch the phosphorus. It will be fired. Where did this heat come from?

Experiment 183.—Put the shank of a large flat-headed carpet-nail into a cork. Put out a small piece of phosphorus, and a similar piece of sulphur, on two separate pieces of tile or plate. Now rub briskly backwards and forwards the brass head of the nail on a piece of hard wood, for a dozen times or so. Now touch the piece of sulphur, and then the phosphorus; the former remains as before, the phosphorus burns. Why is this? Hold a wide-mouthed bottle over the burning phosphorus, to collect the white vapour. Let it stand over the phosphorus.

Experiment 184.—Repeat this experiment, but rub the button on a bar of iron instead of wood. The phosphorus will again be set on fire, but not the sulphur. Note the difference of rubbing the button on iron and on wood. In this case extinguish the phosphorus as soon as kindled. We only want to be sure that there is simply heat enough to kindle it.

Experiment 185.—Take a small iron plate, and a flat-headed hammer, hammer the iron for a short time. You will soon find sufficient heat to fire the phosphorus. In these experiments it is just as well to show that before rubbing or hammering there is not sufficient heat to fire the phosphorus.

Experiment 186.—Take a small piece of cotton or

linen rag. Burn it so that it is thoroughly charred. Collect it in a small wooden box. Now secure a small bar of steel and a piece of flint-stone. Practise striking the steel with the flint so as to get a spark, *i. e.* pieces of steel chipped off red-hot by the flint. Cut some very thin strips of wood or cardboard, dry them, cut them to a point, then melt a little sulphur in a small earthen jar. This must be done very slowly, or the sulphur will get on fire, and the liquid sulphur a dirty brown. When the sulphur has become a limpid liquid, dip the tips of the splints of wood or card into it; they will dry almost instantly. Now strike the steel with the flint in the box containing the charred linen or tinder; the sparks will set fire to the tinder, which will smoulder. Touch the smouldering tinder with the sulphur-tipped strips, they will be kindled. Here you have one of the first forms of lucifer matches ever produced. Light four of them, hold them burning under the mouth of a wide-mouthed jar. The sulphur will soon be burnt off, then withdraw them. Cover the jar to cool.

Experiment 187.—Take some litmus solution, put some water to it, so as to make double the quantity. Now take the jar in which the phosphorus was burnt, and the bottle set aside in the last experiment. Put half the litmus solution into each. Note the change of colour. It is a bright red, and, as you are aware, shows that an acid is present. Where did this acid come from? Take a small piece of phosphorus, and a similar piece of sulphur, put each into a bottle containing some quite clean and boiled or distilled cold water, shake up the bottles. Now

put a similar dose of litmus water into each. There is no change. How is that? Does it not show that heat in each case caused the phosphorus and sulphur to unite with the oxygen of the air when burning, and the combination of each with the oxygen formed an acid? That neither substance by itself is acid is seen by the litmus in the second part of the experiment remaining unchanged.

Experiment 188. — Get a little iodine at the druggist's. A quarter of an ounce will last you a long time if kept in a stoppered bottle, which with bottle should cost you sixpence. Take a small piece of phosphorus, about the size of a mustard seed, dry by gently pressing it with blotting-paper, put it on a tile, a piece of slate, or brick, cover it with a small quantity of iodine. Iodine is of a flaky structure, you must therefore put it flat on the phosphorus. You will see evidences of heating almost immediately, then they burst into flame, giving a dense violet-tinged vapour. Iodide of phosphorus, a new substance, is formed, and in uniting such intense heat is given off as to ignite the substance. You can use a wide-mouthed glass bottle to catch the vapour, which will condense on the inside of the jar.

Experiment 189.—The effect of heat on iodine is worth showing at this stage. Take a clean, dry Florence flask, put into it some few pieces of iodine, warm the flask over the flame of a lamp. The solid passes into vapour without first liquefying, like phosphorus and sulphur. After a very few seconds the flask is filled with a beautiful violet vapour. Remove it from the source of heat, the vapour will go back to the solid, and little shiny flakes will

settle down inside the flask. This process is called sublimation.

Experiment 190.—Pound up separately half an ounce of lump sugar, and about quarter of an ounce of chlorate of potash, the same substance you used for making oxygen. When pounded mix them intimately by stirring them together on a sheet of glazed note-paper; let them be very thoroughly mixed. Now make a heap of it on a piece of brick or tile. Take a piece of glass rod or tube, dip it into sulphuric acid, let the drop fall on to the heap: it will burst into flame almost immediately.

Take a small pinch of chlorate of potash, mix it with some powdered sulphur, put the mixture on a flat piece of iron, on a brick or stone. Give it a sharp blow with a flat-headed hammer. The substance will unite with an explosion and a flash.

From this lesson we learn—

1. That heat arises from several causes.

2. We are again reminded that ordinary burning only goes on in the presence of fresh air.

3. That when such substances as wood are burnt, a part of it goes off into the air, so what is left is not so heavy as before the burning took place.

4. That heat is produced when substances are rubbed together. We have an instance of this in rubbing the hands together in cold weather. We also gave an instance of wood being rubbed till it was kindled in Experiment 182. The common match and fusce are examples of this action. Heat, then, is caused by friction.

5. We also see that some solid substances are fired at comparatively low temperatures. This

reminds us again of the "ignition-point" we mentioned when speaking of gases.

6. We also see that when some substances are burned in air they form acids.

7. Also that heat is caused by bodies striking each other, or "heat is set free by collision."

8. That some substances, when brought into close contact, give off so much heat by the chemical union of their vapours that fire is the result, and new substances are formed (Expt. 188).

The following extract from Mr. E. Douglas Howard's book, *Life with Trans-Siberian Savages*, published August 1893, is interesting, for it shows that the method of kindling a fire by rubbing two pieces of wood together is still in use. He says: "A rough little apparatus was produced consisting of two little blocks of wood. Between these was placed a bit of very dry elm stick, one end, which we will call the lower end, being pointed so as to fit loosely into a hole in the lower block; the other end, also pointed, being in contact only with the flat under surface of the upper block. A bow was then unstrung at one end, the string was passed round the middle of the dry stick, and the free end was loosely re-attached. The bow was then worked with wonderful celerity, until the lower end of the stick first smoked, and then passed into a fitful blaze. This was communicated to some fine dry twigs, and in a few minutes we had as good a bivouac fire as I could wish."

LESSON XX.

SOME EFFECTS OF HEAT ON SOLIDS.

IN our last lesson we learnt that heat could be produced in many ways. We shall in this try its effect on some solids, as in former lessons we saw its effect on air and water.

Experiment 191.—Stretch a piece of copper wire tightly between two upright nails driven into a piece of wood, about 8 inches apart. See that it is quite tight. Now heat the wire between the nails; throughout its length it will hang loose. Take the lamp away, let it cool down, it will be again tight. Heat it again, again it is loose. Try wires of other metals besides copper, the result will be the same.

Experiment 192.—Take a bar of metal about a foot long, and support it at the ends on two blocks; make it fast at one end with a nail or weight, as in Fig. 53, leave the other end loose; put under the loose end a needle with its eye end outwards and projecting over the block, and so laid that it will roll if any movement takes place in the bar. Now attach a straw or spike of grass to the eye end of the needle with a piece of sealing-wax. Place the whole ready for action, the needle so that the straw points directly upwards.

Now light the lamp, put it under the centre of the bar; the bar will, on becoming warm, lengthen, and this will cause the needle to roll, carrying the pointer outwards, further and further, the longer the heat is applied.

Withdraw the lamp, watch the pointer going back to its starting-point as the bar cools. You can repeat this experiment, using a bar of another kind of metal. You will thus find metals do not all expand alike.

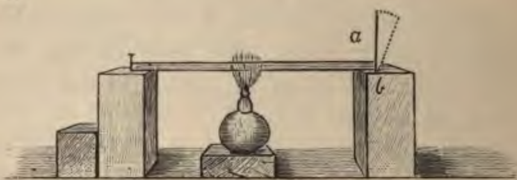

FIG. 53.

Experiment 193.—Get a brass knob-handle of a door, and either a wood or metal curtain-ring, through which the handle will exactly pass. It wants to be a good fit, and to secure this you may have to use a file. Heat the brass handle in the flame of a lamp for a few seconds, then try and drop it through the ring. If it was a good fit before, it will not now pass through till it gets cold. Heat therefore expands solids.

Experiment 194.—Take an iron or brass rod, support it on some blocks near the ends, build a cardboard house leaning on each end of the rod. Now heat the rod—the cardboard structures will be thrown over.

Experiment 195.—Get a flat iron ring that is a trifle too small to put on to a round disc of wood;

put the iron ring in the fire till it gets red-hot. Take the ring out of the fire with tongs, it can now be fitted on to the rim of the disc of wood easily. When nicely fixed, drop the whole into some cold water. Of course a great bubbling and hissing will go on in the water, but that has nothing to do with our experiment. It will presently be cold enough to handle; take it out, try to take off the ring. You cannot do so by any fair means. The rim has contracted with such enormous force that it has pulled even the wood tightly together. This experiment gives us the secret to the wheelwrights' plan of always putting on tires red-hot.

Never put a cold stopper into the neck of a bottle when it is heated, or it will most likely become fast. The expansion of the metal quicksilver in the thermometer has already been referred to.

Experiment 196.—Tie together with thin iron wire a rod of glass and a stout copper wire. Take

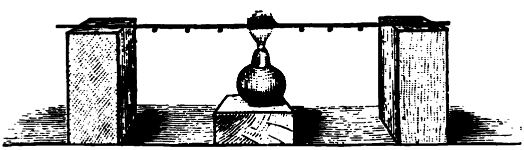

FIG. 54.

some peas or small marbles, stick them on to the rod at equal distances from where they are tied. You can stick them on with wax or solid paraffin. Support the ends of the rod (Fig. 54) and put a lighted lamp at the point where the rods are tied together. The peas on the copper rod will soon fall off, but not so those from the glass.

Experiment 197.—Tie together similar wires of iron and copper. Put a tiny piece of phosphorus on each at about 3 inches from where they are bound together, and a second piece on each about 2 inches further from the first. Now support the rod at the ends, light the lamp, and put it an equal distance between the two. Watch what happens. The first piece of phosphorus on the copper will soon be fired, and most likely the second will be fired before the first on the iron be fired. The copper, then, is a much better carrier of heat than iron.

Experiment 198.—Into a tumbler of hot water put two tea-spoons, one of silver, the other of German silver. Feel the ends of the spoons. You will find the end of the silver spoon soon too hot to hold, not so the German silver.

Experiment 199.—Take a piece of brass tubing and a piece of wood the same size and shape. Wrap tightly round the brass tube a sheet of paper, hold it in the flame of a lamp till the whole gets quite hot. Remove the paper, the inside next the metal will be quite uninjured, and yet the metal itself so hot that you are unable to hold it. Wrap a second piece of paper as tightly round the wood, hold it in the flame; you will not be able to do so long before the paper will be scorched, and perhaps set on fire. What is the reason of this? The metal carries away the heat of the flame so rapidly that it has no time to injure the paper; the wood is so poor a conductor of heat that it cannot afford the same protection to the paper.

Experiment 200.—Take two glass bottles about the same size, fill them with hot water, cork them

up, wrap one completely in two or three folds of flannel, stand them aside for an hour. Then examine them. That which was covered will be nearly as hot as when you left it, the other will be nearly cold. Why is this?

Try another experiment of a similar kind. Fill a bright tea-pot with hot water, touch it soon after it is filled with the naked finger; now put a thin piece of paper between the finger and the tea-pot; now put on a woollen glove, then feel the tea-pot; lastly put a piece of thin sheet lead, such as the chocolate pastilles are wrapped in, round the finger, then touch the hot tea-pot. Explain the various sensations felt, and why they happen.

What do we learn from this lesson? The following are plainly taught—

1. That solids, like liquids and gases, expand on being heated, and contract on being cooled.

2. That metals are very susceptible of this change, but they do not all expand to the same degree.

We have examples of this effect on metals on all sides of us; in hot summer weather the telegraph-wires hang loosely between the poles; that in making railway-lines the rails are not put close end to end. The tubes that bridge the Menai Straits expand considerably on hot summer days, and not only is allowance made for this, but index hands are attached so that the amount of expansion and contraction are registered day by day.

3. That the force exerted by the contraction and expansion is immense.

4. That metals also are good carriers or conductors of heat, but they are not all equally good conductors.

Glass, wood, flannel, and such-like substances are bad conductors of heat.

We make use of bad conductors of heat in our winter clothing, because they prevent the heat from escaping from our bodies.

Glass is a bad conductor of heat, and owing to this, a sudden change from cold to hot, or *vice versâ*, accounts for many breakages among articles made of this material.

APPENDIX.

Apparatus for Experiments.—Although most of our experiments are performed with home-made contrivances and ordinary household appliances, there may be some to whom this course is acceptable who would like to get together apparatus of a little more elaborate construction. We recommend such to get a priced catalogue, of some good maker, to keep for reference. We also advise them not to be led away and get showy apparatus, but such as is simple in contrivance, strong and reliable in its working parts.

Standard Measures.—In our first chapter we have recommended, for the sake of experiment, that each pupil should make a divided measure. A standard measure as a guide to the whole class as well as for the teacher is necessary. For this purpose get a box-wood measure of a metre, having the yard and its divisions marked on it, as well as those of the metre.

The Litre.—Your grocer can probably help you to get an "imperial litre" bottle, which should be kept at hand, as well as a bottle holding exactly the "imperial pint."

Glass Tubes and Rods.—If you wish to have a supply of glass tubing, it is better to get a pound bundle, this will give you tubing of various sizes, and cost you a shilling. We have already given directions for cutting it. If the tube is large, it will be better to file it all round, cutting it rather deeply with the edge of a triangular file. To get

an even cut, wrap round the tube a strip of paper, and cut it round by the paper's edge. Then hold the tube in your two hands, grasping each end tightly with your thumbs meeting over the cut, jerk the ends upwards, and almost in every case your tube will break evenly. Hold the ends in the flame of a spirit-lamp till they are red-hot, then let them cool gradually.

Glass rods may be cut in the same way, and the ends rounded off in the gas-flame.

The method for bending tubes we have already given. We add that a Bunsen's flame will not do. The tube must be heated in a flat flame, so that a long portion of the tube becomes heated.

Do not bend the tube in the flame, or you will have a sharp bend and a contracted tube, and most likely a breakage very soon.

The U *Tubes.*—We have introduced in our experiments for weighing liquids U tubes. These are easily broken, it may be better therefore if you have a ready means of making them for yourself. This you can do by taking two straight pieces of glass tubing, $\frac{1}{4}$ inch or $\frac{3}{8}$ inch, and joining them by a piece of india-rubber tubing. If the ends of the tube are slightly warmed before being put into the india-rubber, they will make good joints, or they may be tied with fine twine or wire.

A buffer of quicksilver may be put into the bend of the tube, if the liquids are likely to mix on touching. Their weights can be taken just the same, the liquids being added till the quicksilver stands at the same height in each tube.

Flasks.—We have recommended Florence flasks, because they can be obtained of the oil-men in almost any place, however remote from town. They are cheap, and can be washed quite free from grease with a solution of soda and water.

For the same reason we have recommended pickle-bottles for collecting gases and similar experiments. Stiff paste-

board can be used as covers for them, if not kept too long under water.

Test-Tubes.—Test-tubes are so useful for many purposes that it is better to have a box of 6 doz. assorted, which will cost you about 2*s.* 6*d.*

India-rubber Tubing.—This tubing is used now for so many purposes, that it can be had in almost every out-of-the-way village. If you have to send a special order for it, get the red, it is the most durable. $\frac{1}{4}$ inch inside diameter is 4*d.* per foot, $\frac{1}{2}$ inch inside diameter 10*d.* per foot.

Corks.—In using corks, use soft, pliable corks. Hard corks are almost useless, they are so likely to break the tubes, and they are troublesome to get into a good shape, therefore frequently they are not air-tight.

Holes can be made through corks either by cork-borers, which are sold in sets, or by a rat-tailed file. The size of a cork can also be slightly reduced by filing the outside, taking care not to spoil the roundness of the cork.

Tapers.—Tapers for testing the various gases are supplied as large-sized vestas. Attach these to stiff wires. They are better than long wax tapers.

The Wire Gauze.—This must be of fine mesh. A piece 6 inches square will cost you 2½*d.* or 3*d.*, or you can get a square foot for 9*d.*

Balloon.—A pretty balloon about 9 inches in diameter, for filling with hydrogen gas, may be had for 1*s.* 6*d.*

Soap Bubbles.—A good mixture for strong film bubbles may be made by scraping into shreds half-an-ounce of Castile soap, put it into a clear glass bottle, cover it with about three-quarters of a pint of distilled, or at least soft water, give it a good shaking once a day for a week, then let it stand aside in a cupboard for a week. Pour off the clear solution into a clean bottle, then add about one-third its volume of pure glycerine, shake it up well to thoroughly mix it. Then stand it aside to settle, when the clear

liquid may be poured off into a stock bottle. Pour out a little for use when required, and if any remains over, do not put it back into the stock bottle. Take pains in making this solution, and be careful in using it. If you cannot get Castile soap use common yellow soap, but never attempt to use fancy soaps, they are generally useless. Good glycerine soap is sometimes used, but the first-named mixture we have found to give very good results.

A bent glass tube from $\frac{1}{4}$ inch to $\frac{3}{8}$ inch in diameter is very suitable for blowing bubbles.

When dropped into a vessel of carbonic acid, a soap-bubble often bursts, rather than float on the gas. This is because the gas contains some free hydrochloric acid, which at once dissolves the film. The gas should be first bubbled through water to wash it free from the acid, then the bubble experiment generally answers.

Chemicals.—Keep these in a safe place under lock and key, out of the way of young people.

Oxygen mixture can be bought at 10*d.* per pound, if you prefer this to mixing the materials as we directed.

Always keep phosphorus under water, and do not let it stand in the light.

Use all the strong acids very carefully, according to instructions already given, and see that the stoppers fit well. Try them every week or so, that they do not get to stick.

When coloured liquids are required to show an experiment to a class, use red ink, or any aniline dye, to colour the water.

Always keep a stock of litmus solution by you, a few drops of methylated spirit mixed with it will preserve it.

Keep also a good stock of lime-water.

Sealing-wax Paint.—Put some bits of sealing-wax into a wide-mouthed bottle, cover them with methylated spirit. The sealing-wax will dissolve. Add more spirit, to bring it down to the required consistency. Apply the

paint with a camel's-hair brush. Stand aside to dry and harden. Do not touch the objects so coated till they are perfectly dry, or finger-prints will be left.

Shellac Varnish.—Put some flake shellac into a wide-mouthed bottle, cover it with methylated spirit. When the shellac is dissolved, dilute the mixture by putting in more spirit.

To varnish woodwork stands for tubes and other items used in experiments.—Coat the object with size. When this is dry put on a thin layer of the varnish. Stand it aside to dry, and do not finger it till the varnish is hard.

Black Varnish.—Grind up together some vegetable black and methylated spirit. Put this when well mixed into a bottle and add more spirit and a few drops of shellac varnish; this makes it stick. Do not put this varnish on too thick, and it should dry a dead black.

To make Glass Troughs.—Cut glass plates of the required size. Warm some bicycle cement, spread a very thin layer along the edges to be joined, warm the edges of the glass, bring them together at the proper angle, hold or otherwise fix them till the cement sets and hardens. Remove the superfluous cement. A vessel so made should be water-tight.

After using apparatus it should be thoroughly cleaned before being put away. If you make a combination for a certain experiment, keep such an arrangement for that experiment only.

Before giving a lesson, get everything ready. Attempt no experiment, however simple, before a class unless you are sure that it will do well. Keep an orderly table. Observe strict cleanliness.

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